uAvionix Response To:

FAA ADVANCE NOTICE OF PROPOSED RULEMAKING (ANPRM)

SAFE AND SECURE OPERATIONS OF SMALL UNMANNED AIRCRAFT SYSTEMS: DOCKET FAA-2018-1086

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1 Introduction

uAvionix is pleased to present the following response to the FAA Advance Notice of Proposed Rulemaking (ANPRM) on Safe and Secure Operations of Small Unmanned Aircraft Systems (sUAS), Docket FAA-1018-1086; Notice No. 18-08.

uAvionix was founded in 2015 with the mission of bringing safety solutions to the unmanned aviation industry to aid in the integration of unmanned aircraft systems (UAS) into the National Airspace System (NAS). It is in this spirit that uAvionix submits these comments. Today, uAvionix produces certified and uncertified ADS-B transceivers, ATCRBS and Mode S transponders, and GNSS position sources for UAS, General Aviation (GA), and Airport Surface Vehicle transceivers. uAvionix is currently in development and test of Command and Non-Payload Control (CNPC) Link systems.

2 Comments

uAvionix specifically wishes to address questions posed by FAA regarding sUAS Critical System Design Requirements. uAvionix will address questions E1-E4 on three different subject matters, corresponding to the principles of "NAVIGATE, SEPARATE, COMMUNICATE" as follows:

1. Performance Based Navigation (PBN) - NAVIGATE
2. ADS-B IN as a standard Detect and Avoid (DAA) component - SEPARATE
3. Command/Non-Payload Control Link (CNPC) - COMMUNICATE

2.1 Performance Based Navigation (PBN)

Performance Based Navigation (PBN) is a topic familiar to the FAA and other Civil Aviation Authorities (CAA) worldwide. The FAA's definition of PBN is as follows:

> "Performance Based Navigation (PBN) is comprised of Area Navigation (RNAV) and Required Navigation Performance (RNP) and describes an aircraft's capability to navigate using performance standards."

To-date, PBN has been implemented largely for commercial manned aircraft receiving air traffic services (ATS). However, the concept of PBN and even the definition above can and should apply to commercial sUAS operations. While Section E of the ANPRM specifically addresses risk reduction through redundancy (or **quantity)** of onboard systems, uAvionix believes that the **quality** of the onboard systems should also be seriously considered as a critical design requirement.

Specifically, uAvionix recommends that a Global Positioning System (GPS) position source with a minimum level of integrity, aided by a Satellite-based Augmentation System (SBAS), and Fault Detection and Exclusion (FDE) / Receiver Autonomous Integrity Monitoring (RAIM) should be required for all Beyond Visual Line of Sight (BVLOS) operations and for Category 3 Operations Over People (OOP) as defined in the FAA's Draft Notice of Proposed Rulemaking (NPRM) for Operation of Small Unmanned Aircraft Systems Over People.

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

Satellite-based Augmentation System (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 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.[i]

Receiver Autonomous Integrity Monitoring (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."[ii]

Fault Detection and Exclusion (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 Global Navigation Satellite System (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.[iii]

Refer to

Figure 1 for the impact of Pseudorange Error on GPS solutions with and without RAIM (which here includes FDE).

Figure 1: Injected Pseudorange Error (Top) and its effects on positioning error without RAIM (Bottom Left) and positioning error with RAIM (Bottom Right) Source: Novatel[iv]

2.1.1 E1. For small UAS operations beyond the visual line of sight of the remote pilot, should the FAA establish design requirements, such as redundancy, for systems critical to the safety of flight? If yes, what should these requirements be and why? Are there other means the FAA should consider to address public safety and national security risks for BVLOS operations?

uAvionix recommends that GPS position sources for sUAS navigation for BVLOS operations be required to have a “minimum level” of RAIM and FDE functionality, and be SBAS compatible. This functionality serves as protection against faults induced by satellite errors or outages, as well as assurance of integrity.

As to the question of whether ALL BVLOS operations require SBAS+RAIM/FDE functionality, uAvionix recommends a performance/risk-based approach. Refer to the risk matrix that FAA has created which places the AIR Aircraft Risk Classes based on Kinetic Energy on one axis against the JARUS SORA Aircraft Encounter Classes (AEC). See Figure 2, Figure 3, Figure 4, and Figure 5.

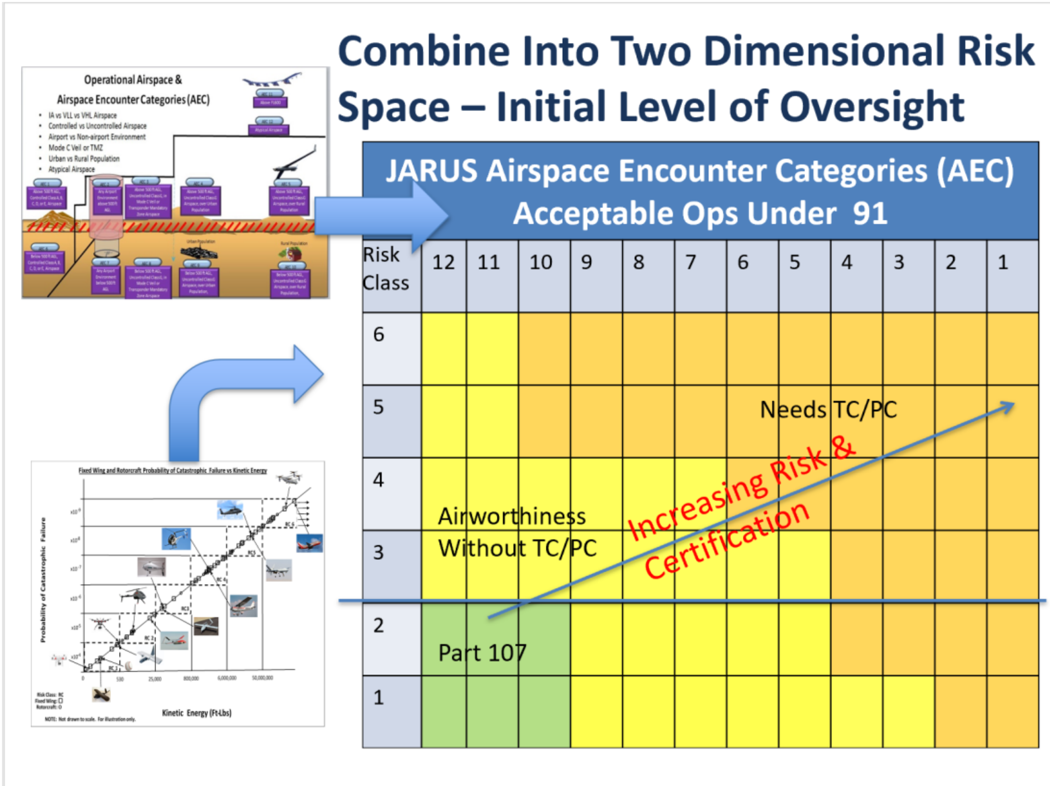

Figure 2: FAA Risk Matrix

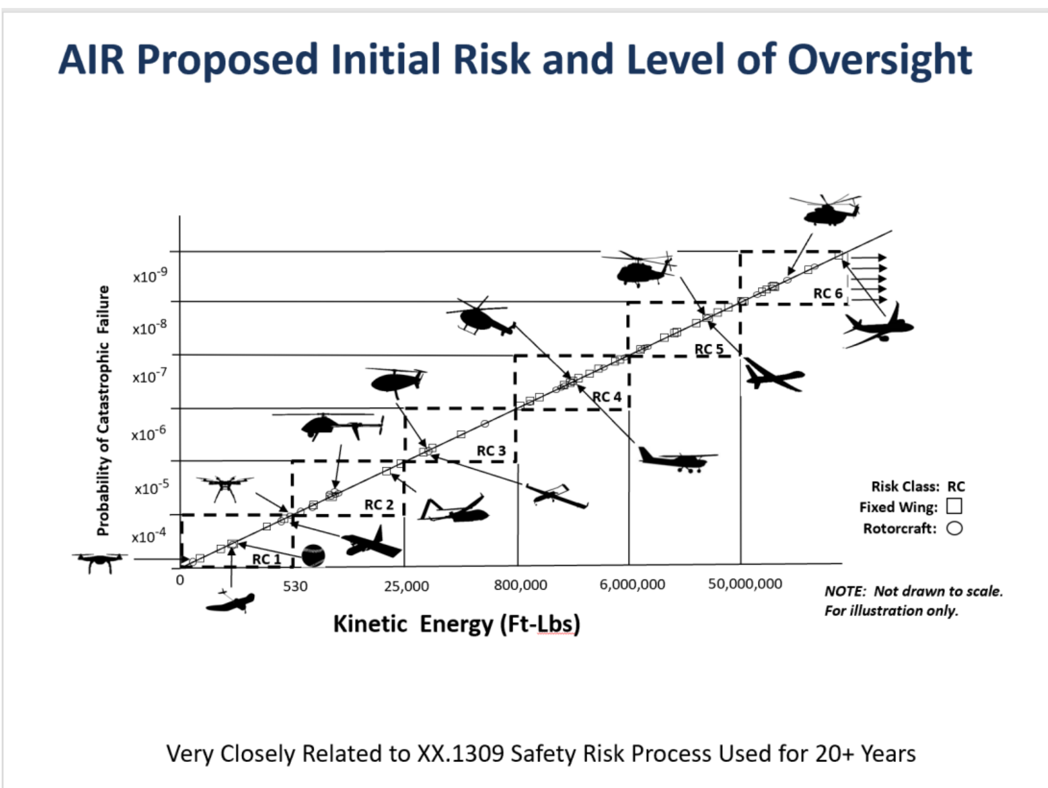

Figure 3: AIR Risk Classes Based on Kinetic Energy

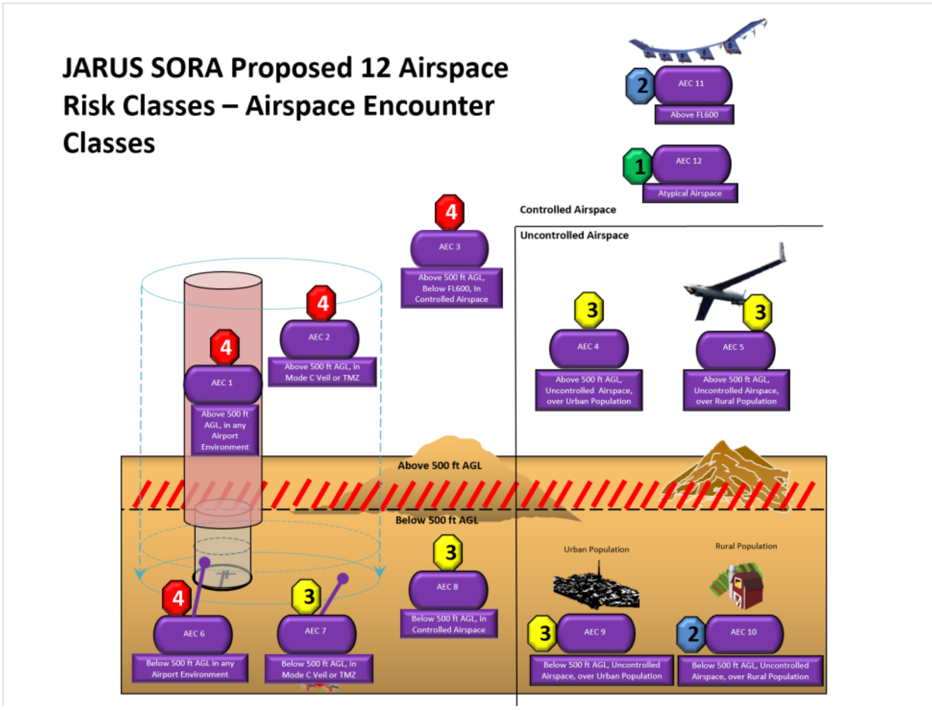

Figure 4: JARUS SORA Airspace Encounter Classes Graphic

Airspace Encounter Categories (AEC)	Operational Airspace
1	Operations within Class A, B, C, D, E, or F Non-Airport Environment above 500 ft AGL
2	Operations within an Airport Environment above 500 ft AGL
3	Operations within Class G airspace above 500 ft AGL within Mode C Veil/TMZ
4	Operations within Class G airspace above 500 ft AGL over Urban population
5	Operations in Class G airspace above 500 ft AGL over Rural population
6	Operations within Class A, B, C, D, E, or F Non-Airport Environment below 500 ft AGL
7	Operations within an Airport Environment below 500 ft AGL
8	Operations within Class G airspace below 500 ft AGL within Mode C Veil/TMZ
9	Operations within Class G airspace below 500 ft AGL over Urban population
10	Operations within Class G airspace below 500 ft AGL over Rural population
11	Operations in airspace above FL600
12	Operations in atypical airspace

Figure 5: JARUS SORA Airspace Encounter Classes Text

uAvionix is proposing the following guidelines for requiring navigation system GPS with SBAS+RAIM/FDE or BVLOS Operations:

- AIR Risk Categories 2-7
- In ***any one*** of the following AECs
  - >500' AGL
  - Within controlled airspace, Mode C Veil, or transponder mandatory zone (TMZ)
  - Over Urban Population
  - Within an airport environment

Refer to Figure 6 for a depiction of the FAA Risk Matrix annotated with these recommendations. Risk entries marked with an "X" indicate the recommendation of GPS RAIM/FDE for the combination of that aircraft risk class and AEC location.

JARUS Airspace Encounter Categories (AEC)
Acceptable Ops Under 91

Risk Class	12	11	10	9	8	7	6	5	4	3	2	1
6						X	X	X	X	X	X	X
5			X	X	X	X	X	X	X	X	X	X
4			X	X	X	X	X	X	X	X	X	X
3			X	X	X	X	X	X	X	X	X	X
2				X	X	X	X	X	X	X	X	X
1												

Figure 6: Recommendation for navigation GPS with RAIM/FDE for BVLOS Operations

2.1.2 E2. For small UAS operations over people that exceed the NPRM safety thresholds indicated above and therefore must seek a waiver to 107.39 to operate over people, should the FAA establish design requirements such as redundancy, for systems critical to safety of flight? If yes, what should these requirements be and why? Are there other means the FAA should consider to address public safety and national security risk for operations over people?

The FAA has proposed changes to Part 107. The NPRM "proposes to allow routine operations over people without a waiver or exemption under certain conditions. The applicable conditions vary depending on the level of risk the small UAS operations present to people on the ground."[vvi] In the NPRM, the FAA proposes three categories of permissible operations over people based on the risk of injury they present. A summary of the categories is as follows:

1. Category 1 – sUAS (including payload) weighing less than 0.55 pounds
2. Category 2 – sUAS weighing more than 0.55 pounds which are designed in such a way that impact with a person would be minimal, transferring less than 11 ft-lbs. of kinetic energy, contain no exposed rotating parts, and does not have an FAA-identified safety defect.
3. Category 3 - sUAS weighing more than 0.55 pounds which are designed in such a way that impact with a person would be minimal, transferring less than 25 ft-lbs. of kinetic energy, contain no exposed rotating parts, and does not have an FAA-identified safety defect. Category 3 also contains operational restrictions to reduce risk to injury on the ground.

uAvionix recommends that Category 3 operations over people be considered for requiring GPS with SBAS+FDE/RAIM functionality. On a case-by-case basis, Category 2 would benefit from these solutions as well.

2.1.3 E3. Are there other types of small UAS operations besides BVLOS and operations over people that the FAA should establish design requirements for, such as redundancy, to address public safety and national security risk?

There are other scenarios, which even when conducted within the boundaries of Part 107 without a waiver may benefit from critical design requirements such as RAIM/FDE functionality for the primary GPS navigation source, due to the increased risk of accident or risk to national security. These scenarios may include the following:

- Operations on airport grounds or in runway approach or departure paths.
- Operations intentionally conducted in close proximity to operating manned aircraft such as search and rescue, firefighting, or law enforcement operations.

2.1.4 E4. What are the costs and benefits to incorporate redundant systems critical to safety of flight for BVLOS operations or operations over people that exceed the NPRM safety thresholds indicated above?

SBAS+FDE/RAIM functionality is a characteristic rarely available in non-aviation GPS receivers. As a result, the cost of a GPS with SBAS+FDE/RAIM will be more expensive than a Commercial-Off-The-Shelf (COTS) GPS without. Incorporating redundancy of non-integrity GPS also adds additional costs, it fails to address faults which a GPS with integrity (SBAS+FDE/RAIM) is designed to exclude. When a GPS satellite experiences a failure that creates Signal in Space errors, it makes no difference if an sUAS incorporates one or two or ten COTS GPS receivers. All will exhibit identical fault behaviors. Further, a GPS with SBAS+FDE/RAIM notifies the autopilot or remote pilot in command (RPIC) regarding the health of the solution, allowing the RPIC to make informed operational decisions. A GPS lacking this functionality, having computed a bad position, cannot provide its measure of integrity to the autopilot or RPIC.

uAvionix has pioneered GPS certification based on a complex COTS GPS receiver. In 2018, uAvionix certified its truFYX TSO-C145d GPS as a packaged component of its skyBeacon ADS-B OUT solution for General Aviation (GA). In Q2 of 2019, uAvionix will complete certification of the truFYX GPS in a stand-alone version under TSO-C145e. TSO-C145e Class Beta-1 is intended to be a position source for an integrated navigation system for oceanic and domestic en route, terminal, LNAV approach, and departure operations. The COTS hardware platform provides for affordability in an aviation-grade GPS never before achieved.

In 2017, uAvionix received TSO-C199 Class B certification for its FYXNAV product. As stated in the TSO: "The intent of this TSO is to allow the use of commercially available GNSS position sources. The receiver must be capable of using SBAS provided corrections and health messages […]. The receiver may continue to provide position when outside of SBAS coverage or when using unmonitored satellites."[vii] The TABS TSO does prohibit a Class B device from being the position source of a certified navigation system. However, it goes on to say that "TABS can potentially act as a low-cost platform for other aviation applications."

TABS Class B FDE Capabilities. The following statements and requirements depict the RAIM/FDE functionality of a TABS Class B GPS. This functionality is not available in a COTS GPS receiver.

- A1.2.6.1 The GPS constellation experiences a significant ramp error approximately once a year. During these events, a chipset which uses SBAS will detect and either correct or exclude the faulty satellite.
- A1.2.6.4 The GNSS position source SHALL detect a pseudorange step greater than 700 meters. If a step of greater than 700 meters is detected, measurements from the affected satellite SHALL be excluded.
- A1.2.6.7 The GNSS position source SHALL not use SBAS corrections when the SBAS satellite is broadcasting message type 0.
- A1.2.6.8 The GNSS position source SHALL exclude satellites with EDREI=15 reported in the SBAS fast corrections.

Figure 7: TSO-C199 FYXNAV (Left) and TSO-C145e truFYX (Right)

2.2 ADS-B IN

It is an assumption that any sUAS operation operating 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 integration. uAvionix, as well as other manufacturers, now provide ADS-B IN receivers as OEM modules and add-on functionality for sUAS (see Figure 8). uAvionix receivers can be found in high profile sUAS OEMs such as X (Google Wing), Quantum Systems, and DJI.

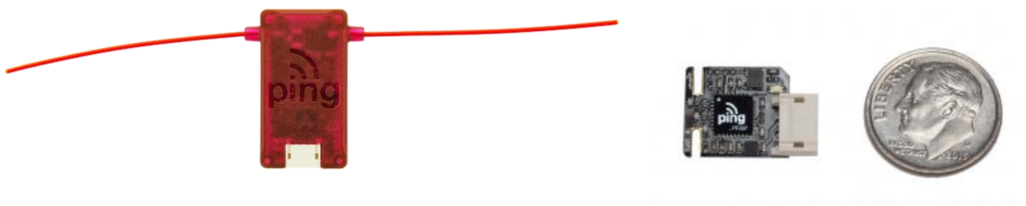

Figure 8: uAvionix ADS-B Dual-Band Receivers are available as aftermarket and OEM options

Even though not all Part 91 aircraft are required to equip with ADS-B OUT as a result of the ADS-B mandate, estimates are that 100,000-160,000 aircraft will be. By enforcing ADS-B IN equipage on BVLOS sUAS, manned/GA aircraft owners have additional incentive to equip with ADS-B OUT to make their aircraft conspicuous to any sUAS operating in their vicinity. In this way, FAA has the opportunity to initiate a virtuous circle, providing yet another safety enhancing benefit (in addition to services such as TIS-B, FIS-B, and ADS-R) to GA pilots who equip with ADS-B OUT, even if they do not fly within the airspace defined by 14 CFR 91.225.

2.2.1 E1. For small UAS operations beyond the visual line of sight of the remote pilot, should the FAA establish design requirements, such as redundancy, for systems critical to the safety of flight? If yes, what should these requirements be and why? Are there other means the FAA should consider to address public safety and national security risks for BVLOS operations?

FAA should establish a design requirement for sUAS BVLOS operations in the United States in which the BVLOS aircraft is required to incorporate on-board ADS-B IN as a component of the DAA solution. In some locations (e.g. within the Mode C Veil after January 1, 2020), a cooperative-only (ADS-B IN) solution may be sufficient as a complete DAA solution, subject to the safety case of such operations.

2.2.2 E2. For small UAS operations over people that exceed the NPRM safety thresholds indicated above and therefore must seek a waiver to 107.39 to operate over people, should the FAA establish design requirements such as redundancy, for systems critical to safety of flight? If yes, what should these requirements be and why? Are there other means the FAA should consider to address public safety and national security risk for operations over people?

As long as operations over people occur within visual line of sight, uAvionix does not advocate required ADS-B IN equipage for these operations, regardless of aircraft/operations category.

2.2.3 E3. Are there other types of small UAS operations besides BVLOS and operations over people that the FAA should establish design requirements for, such as redundancy, to address public safety and national security risk?

There are other scenarios, even when conducted within the boundaries of Part 107 without a waiver, which may benefit from ADS-B IN functionality, due to increased risk of accident when operating in close proximity to manned aircraft. These scenarios include the following:

- Operations on airport grounds or in runway approach or departure paths.
- Operations intentionally conducted in close proximity to operating manned aircraft such as search and rescue, firefighting, or law enforcement operations.

2.2.4 E4. What are the costs and benefits to incorporate redundant systems critical to safety of flight for BVLOS operations or operations over people that exceed the NPRM safety thresholds indicated above?

uAvionix pioneered the miniaturization of ADS-B technology, bringing it to a SWaP-C compatible with widespread UAS operations. ADS-B IN is not only the lowest-cost DAA component which can be added to a sUAS platform, but also the most effective and highest performing. This came about thanks to a combination of the existing ADS-B mandate and core operations of the technology yielding detection ranges that far exceed the DRAFT sUAS “Well Clear” definition proposed in draft Advisory Circular (AC) 90-WLCLR.

While ADS-B IN alone cannot provide a complete DAA solution, it should be considered the first and primary technology used in a multi-sensor application. Its use should be required for BVLOS operations. As mentioned previously, this requirement will encourage ADS-B OUT equipage by GA aircraft which otherwise may not do so. This GA equipage increases the effectiveness of an ADS-B IN sUAS policy, helping to create an airspace where everyone can SEE and BE SEEN, significantly reducing the risk of mid-air collision (MAC).

Costs vary by volume. In low quantities, uAvionix sells an “add-on” product called PingRX which is a dual band ADS-B receiver, retailing for $249 USD. In addition to this turnkey product, uAvionix produces chipsets and OEM modules for high-volume customers which can result in significantly lower costs. uAvionix prefers not to disclose product cost basis in a public forum like this ANPRM, but is willing to disclose pricing details directly with the FAA.

2.3 Command and Non-Payload Control (CNPC) Link

Figure 9 illustrates the Command and Non-Payload Control (CNPC) Link System components, as described in FAA TSO-C213.

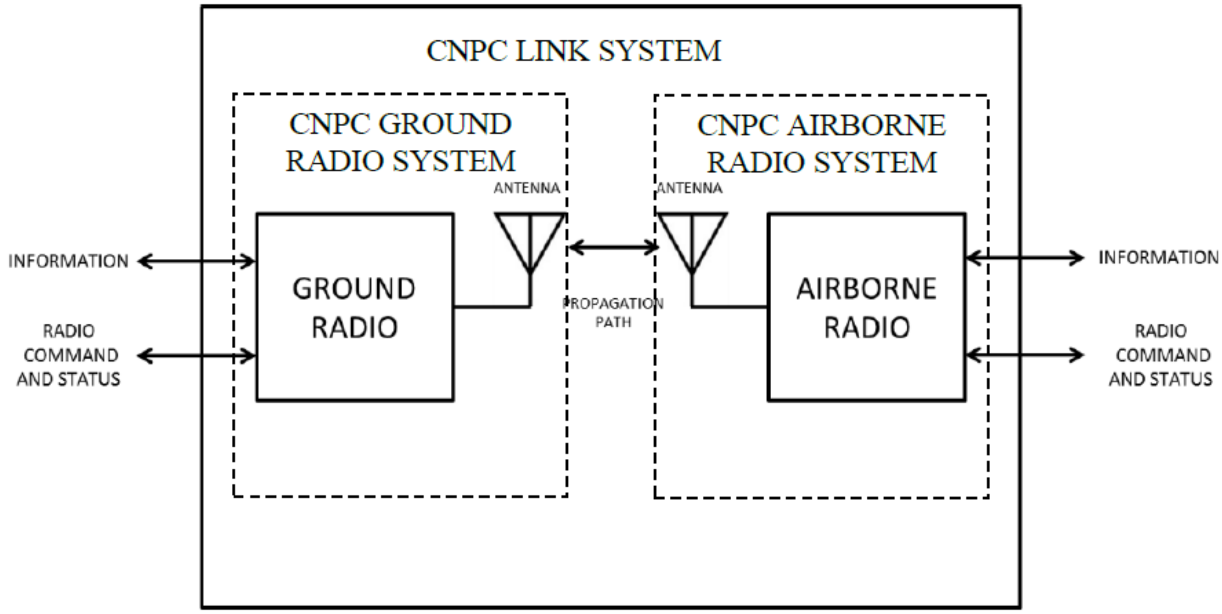

Figure 9: CNPC Link System Components

According to RTCA DO-362 – Minimum Operational Performance Standards (MOPS) for the UAS CNPC link system:

> *"the word 'Control' refers to the information exchanges needed to support the pilot in safely maneuvering the unmanned aircraft (UA) on the ground and in the air. This would include commands to the UA such as: executing turns, changes in engine operation, changes in radio frequencies, etc., and information from the UA such as: confirmation of receipt of and actions taken in response to commands, as well as detect and avoid information, navigation data, weather radar data, onboard situational awareness data, etc. The words 'Non-Payload Communications' includes the potential of the CNPC Link System to support pilot-to/from-ATC voice and data communications. However, non-payload communications specifically exclude communications associated with the UA mission payloads which should not contain safety-of-flight information."*

The robustness of the CNPC link should be considered in the context of the robustness of the autonomy functions of the autopilot. In other words, if the autopilot's autonomous functions are non-deterministic, a more robust CNPC link is required to support Pilot-in-the-loop (PITL) actions. PITL refers to a UA pilot who directly controls the aircraft flight path, while Pilot-on-the-loop (POTL) refers to a UA which has capability to perform many flight functions but with a human providing oversight; e.g. activation/deactivation instructions. In short, PITL employs less autonomy than POTL. Many autopilots can support both PITL and POTL.

Currently uAvionix is unaware of any standards development regarding autopilot autonomous functionality. In order to ensure safe and secure operations, it is necessary to focus on the robustness of the CNPC link system. Two major components of the CNPC Link System need to be considered:

1. Design Assurance Level (DAL) – this could be rephrased as "certification" or "qualification" or in any number of ways, but DAL nicely captures the intentional system design, engineering, and testing processes undertaken to support safety-of-life systems. This is a familiar concept to the NAS, as airborne DAL levels are defined in RTCA DO-178, and ground system DAL levels in RTCA DO-278.
2. Spectrum Selection – there are four types of spectrum which could be utilized for CNPC applications. Refer to Figure 10 for the cost vs interference risk plot of these options.
    a. Unlicensed Spectrum – Today most UAS CNPC solutions are using unlicensed spectrum. Examples of this spectrum include the 2.4GHz "Wi-Fi" frequencies and Industrial, Scientific, and Medical (ISM) bands. Equipment operating in unlicensed spectrum **must not cause interference**, **must expect interference**, and **have no Right to Operate**. This means the spectrum is <u>not legally protected</u> for any specific use, including UAS CNPC. Unlicensed spectrum is the lowest cost, but highest risk of all spectrum options.
    b. 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 <u>legally protected</u>, but **must not cause interference**, and **must accept interference from primary and secondary users**, and has **no Right to Operate over other licensed users**.
    c. 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.
    d. 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. Licensed Single Primary Use is the highest cost and lowest risk of all options.

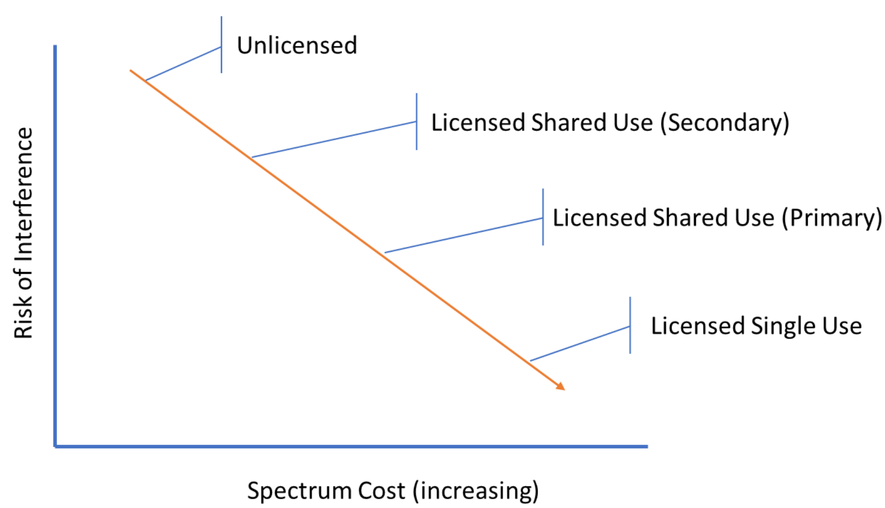

Figure 10: Spectrum Options: Interference Risk vs. Cost of Spectrum

2.3.1 E1. For small UAS operations beyond the visual line of sight of the remote pilot, should the FAA establish design requirements, such as redundancy, for systems critical to the safety of flight? If yes, what should these requirements be and why? Are there other means the FAA should consider to address public safety and national security risks for BVLOS operations?

Design Assurance Levels

FAA TSO-C213 for UAS CNPC Terrestrial Link System Radios[viii] includes the following Figure 11 which defines the appropriate DAL based on the Kinetic Energy Risk Classes defined in Figure 3. uAvionix recommends the FAA adopt the policy that this DAL guidance become mandatory for the defined risk classes of BVLOS operations.

Risk Class	Kinetic Energy in Ft-Lbs	Design Assurance Levels (DAL) and Probability of Catastrophic Failure
1	≤ 529	DAL E, 10^{-4}
2	≥ 530 to $\leq 24{,}999$	DAL D, 10^{-5}
3	$\geq 25{,}000$ to $\leq 799{,}999$	DAL C, 10^{-6}
4	$\geq 800{,}000$ to $\leq 5{,}999{,}999$	DAL C, 10^{-7}
5	$\geq 6{,}000{,}000$ to $\leq 49{,}999{,}999$	DAL B, 10^{-8}
6	$\geq 50{,}000{,}000$	DAL A, 10^{-9}

Figure 11: UAS Risk Classes and Design Assurance Levels Based on Kinetic Energy

Spectrum

FAA should establish a design requirement for sUAS BVLOS operations in the United States in which the BVLOS aircraft is **prohibited from using unlicensed spectrum for CNPC purposes**. Additionally, the CNPC Link System should be encouraged to use Licensed Shared Primary Use or Licensed Single Use for BVLOS operations. A risk-based scale of available spectrum should be developed for the various Risk Classes defined in Figure 3.

2.3.2 E2. For small UAS operations over people that exceed the NPRM safety thresholds indicated above and therefore must seek a waiver to 107.39 to operate over people, should the FAA establish design requirements such as redundancy, for systems critical to safety of flight? If yes, what should these requirements be and why? Are there other means the FAA should consider to address public safety and national security risk for operations over people?

While the focus of 2.3.1 is on operations Beyond Visual Line of Sight, it is worth noting that once command and control of the UAS is lost, it does not matter whether the aircraft is within sight or not! As a result, uAvionix makes the same recommendations for OOP as for BVLOS operations, as the risk is high to persons on the ground if the CNPC link is lost.

2.3.3 E3. Are there other types of small UAS operations besides BVLOS and operations over people that the FAA should establish design requirements for, such as redundancy, to address public safety and national security risk?

There are other scenarios, even when conducted within the boundaries of Part 107 without a waiver, whose operations may benefit from specific DAL values and protected spectrum, due to the increased risk of accident brought on by close proximity to manned aircraft. These scenarios include the following:

- Operations on airport grounds or in runway approach or departure paths.
- Operations intentionally conducted in close proximity to operating manned aircraft such as search and rescue, firefighting, or law enforcement operations.

2.3.4 E4. What are the costs and benefits to incorporate redundant systems critical to safety of flight for BVLOS operations or operations over people that exceed the NPRM safety thresholds indicated above?

There is no question that higher DAL values and the use of protected spectrum come at increased cost. Similarly, sensor redundancy comes at increased cost, but further penalizes the host sUAS by increasing the SWaP burden. The result is a lower payload allowance or reduced flight time. In contrast, Design Assurance has no "SWaP Penalty".

The CNPC link is critical for safe operation and, as discussed previously, acts as a safety backstop against non-deterministic autopilots with varying levels of autonomy and developed independent of any existing standard. uAvionix is fortunate to have experience, not only with development of commercial radio control (RC) C2 solutions, but with certified ADS-B, transponder, and GNSS commercial products. The result is a reduction of overall SWaP and cost. For CNPC, this makes for a radio solution akin to today's commercial hobby RC market.

[i] https://gssc.esa.int/navipedia/index.php/SBAS_Fundamentals
[ii] https://en.wikipedia.org/wiki/Receiver_autonomous_integrity_monitoring#RAIM

[iii] https://en.wikipedia.org/wiki/Receiver_autonomous_integrity_monitoring#Fault_detection_and_exclusion
[iv] https://www.novatel.com/assets/Documents/Papers/RAIM.pdf
[v] https://ww.faa.gov/uas/programs_partnerships/DOT_initiatives

[vii] http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgTSO.nsf/0/1600df588a6f53ae86257d710070d105/$FILE/TSO-C199.pdf
[viii] http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgTSO.nsf/0/BDEFA726EA8CDD8086258250005F071E?OpenDocument