



VIGILAIR

Enabling UTM

VigilAir for Unmanned Aircraft Systems Traffic Management

Whitepaper

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Introduction

Commercial drones have made tremendous strides in recent years in both technological capabilities as well as availability and functionality, and it seems that these changes are just the beginning of a much more comprehensive development. In the coming years, drones are expected to take on ever-increasing roles in more and more different aspects of our lives. With fields as varied as delivery and transportation, mapping and monitoring, infrastructure inspection and maintenance, security and HLS, it is evident that drones are poised for major breakthroughs and advances.

This coming change is not without its tasking challenges, some of them quite novel and unique to this field. As the overall use of drones greatly expands, as drones' tasks and missions vary and evolve and as drones engage more and more in Beyond Line Of Sight (BLOS) flights, it is clear that airspace management becomes a key requirement in enabling the safe maturity of the "Drone Dream". While regulation of airspace is key to the success of drones, technological solutions are required to enable the successful realization and enforcement of such regulation.

The large scale, yet safe, usage of drones will require multiple new and veteran stakeholders to work in harmony to enable the successful real-time operation of large numbers of drones. These include drone providers, drone operators, drone services' consumers, aviation authorities, air navigation service providers, communication service providers and more. And while drones' autonomous Detect and Avoid (DAA) capabilities are improving, it is clear that a centralized approach to airspace management is also required, to ensure the safety and security of drone operations. Unmanned aircraft Traffic Management (UTM) systems are clearly mandatory.

UTM systems will face multiple challenges, and these will have to be mitigated if the expected 20% annual compound growth rate (CAGR) of the UTM market is to be realized and maintained. These challenges are especially severe in high drone congestion areas (such as corridor convergence areas and flight hubs), in urban environments and with the expected reality of uncooperative and rogue drones. UTM systems will have to face strict operability, safety and security requirements to support heavy drone use.

VigilAir is Vorpai's response to these challenges. VigilAir, Vorpai's RF-based state-of-the-art drone detection, geolocation and tracking solution, provides unique drone situational awareness with extremely high accuracy and great clarity. VigilAir can be cost-effectively deployed over wide areas, acting as a major UTM building block to provide unique and actionable drone information that other systems, sensors and technologies simply cannot generate.

This whitepaper discusses why VigilAir should be a core component of future UTM systems, providing unique information that will complete UTM integrity and solve multiple use-cases and scenarios that are expected to prevent the successful deployment of these systems.

UTM—A critical challenge to drone success

Successful airspace management is key to the long-term success of drone deployment and usage. The large-scale operation of multiple types of drones, in varied missions, in dense urban environments and BLOS all present novel challenges. In many ways, concepts relevant to 2-dimensional operation of large transportation fleets, something we take for granted as possible and achievable, accrue unique complexities when transferred to the envisioned 3-dimensional world of large numbers of unmanned aerial vehicles. In the same manner, successful concepts employed in the airspace operation and management of manned aircraft, evidently successful in today's modern world, cannot be directly transferred to the expected scenario of much larger numbers of unmanned vehicles operating in much closer proximity to people and assets. An additional complexity of UTM shortcomings that must be taken into consideration is that existing large-scale technologies and operational concepts employed in modern mass transportation (automobiles, ships, railways, commercial aircraft etc.) cannot be easily and fully cloned to the drone and UTM world. This is so because the migration to an unmanned scenario removes multiple fallbacks that can mitigate potential mis-

takes today (no more "human in the loop"), while the 3-dimensional nature of the problem forewarns of more severe outcomes of such mistakes (a drone "fender-bender" now means objects will fall from the sky, not stop at the side of the road).

A critical look at future UTM systems, certainly required to ensure comprehensive top-quality safety and security, needs to consider not only the straightforward and benevolent usage of drones, but also the malicious, criminal and terrorist actors who have already shown that they can and will use drones to achieve their nefarious purposes. Proper planning of UTM safety and security must consider the need for supportive and additional failsafe and fallback systems, to overcome and compensate for the reliance of UTM on stakeholders' cooperation and lawfulness. Effective and comprehensive mitigation of drone-related threats now needs to take into account not only the cooperative drone, but also the non-cooperative and rogue drones, *and* their operators, as the criminal can now be physically separated from the tools of his crime.

Some of the main challenges UTM systems will be facing are:

Very wide coverage requirements – Drones are expected to fly at low and me-

dium altitudes at large numbers, through flight corridors and urban areas alike. This means that UTM systems will be required to monitor and control very large airspaces, unlike modern commercial (manned) aviation where most control is done locally at airports and relies on aircraft self-reporting and on-board man-in-the-loop capabilities. To make issues more complex, many of the methods used to control modern airspaces are very limited, if at all deployable and functional, in urban areas.

Real Time Visibility – UTM systems will not be just about authorizing future drone flights and expected drone operations, then managing that data and information offline. In order for UTM to be successful, real-time visibility, enforcement and regulation will also be required so that UTM can be successfully and safely realized. Achieving such real time visibility, for large numbers of drones flying over huge areas is a weighty technological challenge.

Non-Cooperative Drones and Operators - Current UTM visions and frameworks are based on the basic premise that drones and their operators will be cooperative, that is that all operators will register their drones and their flights, that no equipment will be tampered or spoofed and that no external interference with UTM will take place. We can hardly assume that will be the actual case, and in

reality, there will be events where:

- Malicious (or just clueless, or careless) actors will not bother to register their drones, nor submit and log their flight paths, or will list and register false information
- Malicious actors will disable or spoof electronic “license plates” to hide their activities or generate false drones supposedly traveling within the airspace, disrupting the UTM operations of real drones

Autonomous positioning reliability-

In order to navigate successfully and reach its destination, a drone needs to know its own location. UAS will use Global Navigation Satellite Systems (GNSS) as well as, perhaps, ground based additions to such systems (e.g. DGPS), being the most widespread, easy and cheap solution to this requirement. But, positioning reliable enough to support autonomous aerial vehicles operation is in reality hard to achieve since:

- Drones are expected to operate extensively in urban areas. GNSS reception in dense urban areas typically exhibits reliability and continuity lapses, lowering overall performance. In addition, interference from unintentional transmissions and electronic sources, common in cities, lower the availability, reliability and performance of GNSS signals.

- GNSS is susceptible to both jamming and spoofing.

Drone identity and tracking –Successful operation of UTM is expected to start with drone registration and with flight-path submission and logging. In addition, some forms of drone “electronic license plates” are being considered (e.g. transponders, ADS-B like transmitters etc.). While both are expected to be main enablers of widespread drone use, relevant limitations include:

- Malicious actors will not bother to register their drones, nor submit and log their flight paths
- Malicious actors will disable or spoof electronic “license plates” to hide their activities or generate false drones supposedly traveling within the airspace, disrupting UTM operations of real drones
- Millions of drones that are already in use, have not been registered nor carry any type of transponder or electronic “license plate”

It is worthwhile to remember that the expected safety and security impact of an unregistered drone flying an undeclared flight path with false “number plates” can be expected to be quite different and more severe, than that of a criminal riding about town with a stolen vehicle and forged license plates.

Technical malfunctions – No technology is perfect, and some malfunctions in navigational aids can be expected. In the drone and UTM domains, the outcome of such faults can be of dire consequences, as there is no human on-site to take direct control of the situation, while the 3-dimensional nature of a technical malfunction event may generate, on the ground below, a much more severe impact.

Drone accessibility and vulnerability – Drones are and will remain more physically accessible to both clueless as well as criminal actors, making them more vulnerable to tampering and modification. This makes drones’ tampering and modification a much more realistic and probable event than a similar event involving commercial manned airliners.

Vorpai’s VigilAir is a unique solution, successfully rising to the challenge of providing real-time, independent, accurate and detailed drone situational awareness, a solution that can deliver unique information that is highly relevant for mitigating UTM’s main shortcomings.

VigilAir

Introducing VigilAir

VigilAir is Vorpai's flagship solution for extremely high accuracy and wide area drone situational awareness, enabling drone management and counter drone operations carried out by civilian and military organizations.

As drones increasingly become an everyday part of our lives, the needs to monitor and manage large numbers of drones in densely populated areas will grow in-hand. UTM systems are envisioned and planned, but they all have their inherent shortcomings, born from the very nature of the UAV domain.

VigilAir is Vorpai's answer to these challenges, providing an unparalleled level of accuracy and clarity in drone situational awareness. With extremely sensitive detection and highly accurate geolocation, VigilAir detects, geolocates and tracks drones with uncanny precision. This acute situational awareness can provide UTM systems with independent, real-time, wide coverage, long range accurate and detailed information which can enable the safe and secure prevention, avoidance and management of mishaps associated with clueless users, malicious actors, technology shortcomings and technical malfunctions.

Functionality and Capabilities

Drone Detection and Geolocation

VigilAir enables the detection of drone RF communication and data links and broadcasts at great distances and with extremely high sensitivity, even in high noise and urban environments. This is done by employing advanced signals processing algorithms and procedures, optimizing the utilization of the carefully selected hardware, and leveraging years-long experience with the interception of multiple types of RF signals in general and Drone RF emissions in particular.

VigilAir's RF-based detection method does not require any RF transmission, is fully passive and as such does not require any regulatory compliance, spectrum licensing or certification. VigilAir does not interfere, therefore, with any electronics or communication systems, making it a system that's easy, safely and legally allowed to be installed anywhere, including urban environments, airports and sensitive sites and locations.

Employing Vorpai's proprietary enhancements to radically power-up geolocation technology, VigilAir provides real-time and highly accurate geolocation of large numbers of drones. This mass localization provides reliable, timely and clear information on hundreds and even thou-

sands of drones' locations and activities over extensive geographical zones.

Drone Tracking

Multiple consecutive geolocations of the same drone enable the generation of a continuous drone track. VigilAir carefully filters and integrates raw detection and geolocation information to generate a continuous high-fidelity moving target indication of multiple drone tracks. Since the geolocation data is highly accurate, the resulting tracks provide actionable intelligence for the clear comprehension of the aerial situational picture and for optimizing the management of drone-related events and emergencies.

Drone-Operator Geolocation

While alternative drone management technologies (radar, optical, IR etc.) are blind to the drone-operator's presence and location, VigilAir can geolocate the *source* of the command and control (C2) *uplink* source, in effect accurately locating the drone *operator*. Vorpai's situational awareness picture thus includes drone *operator* geolocation information, and even operators on the move (e.g. on foot or in a vehicle) can be accurately tracked. This unique information is an important addition to a UTM system's knowledge-arsenal for enabling correct and full comprehension of the drone situation. It is also the enabler for root cause prevention

and mitigation of drone related events, by enabling the apprehension of clueless, careless or criminal actors, whether one-time or repeat offenders. Drone operator geolocation, with the unique VigilAir accuracy, provides UTM frameworks with the situational intelligence enabling the efficient identification, and when needed – apprehension, of drone operators and the successful and complete termination of repeat drone offenses. This capability, unique to VigilAir, will have a powerful deterrent effect on potential malefactors, as it becomes common knowledge that drone operators, not just drones, are within view of UTM systems and the reach of law enforcement agencies.

Drone Situational Awareness Picture

The VigilAir SystemCenter generates a holistic drone aerial situational awareness picture, which can be displayed on screen locally, or easily viewed on remote devices (PCs, Tablets, Mobiles) using a browser. The information can also be exported to external systems over an easily configurable interface, using common protocols or according to customer-defined requirements. VigilAir can thus be easily and quickly integrated into existing and future ATC and UTM frameworks, where its unique real-time information can be integrated with that of other sources, greatly enhancing overall system performance.

Regulation and Compliance

VigilAir is a system employing only passive RF sensors, it does not transmit, radiate or otherwise influence its surroundings. Therefore, VigilAir does not require any spectrum allocation, frequency use deconflicting, electronic compatibility certification or health-related regulatory compliance. In addition, Vorpai's algorithms can analyze the "raw" RF waveforms without decoding, demodulating or otherwise accessing the transmissions' content, avoiding any possible breach of privacy and cyber-related rules and regulations. This makes VigilAir a system that's easy and legal to deploy, requiring no certification, licensing or regulatory permits of any kind, including in urban areas and sensitive zones like airports and critical infrastructure.

VigilAir — Empowering UTM

VigilAir provides a plethora of unique advantages which can mitigate UTM systems' main shortcomings, enabling an effective and more powerful UTM deployment to truly support an efficient, safe and secure operation of massive numbers of drones in congested and urban airspace. Let's review these advantages.

Detailed and Robust Real-Time Drone Situational Awareness

VigilAir provides a real-time, robust and detailed drone situational awareness picture based on sensitive detection and accurate geolocation and tracking of drones' and operators' RF signals. This drone situational awareness is provided for both cooperative and non-cooperative drones, as well as for lawful and lawless drone operators. It is this acute drone situational awareness, coupled with the advantages detailed below, which makes VigilAir a core enabler for successful UTM services, where pre-planning and registration can be coupled with real-time enforcement, verification and regulation.

Wide Coverage

VigilAir requires the deployment of multiple RF sensors to generate drone detection, geolocation and tracking information. The sensors are usually deployed

on the perimeter of a polygon, with sensitivity and accuracy best within the polygon, decreasing with distance from it. The commonly required distances between sensors are 2-4 Km (1.2-2.4 mi) in an urban environment and 3-6 Km (1.9-3.7 mi) in a rural environment. These very large distances between sensors mean that coverage of extremely large areas, of tens and even hundreds of kilometers, can be scaled up easily. With these distances between sensors, VigilAir deployments can be easily realized over already existing grids such mobile networks' infrastructure, smart city points, municipal infrastructures and the like. Vorpai's proprietary algorithmic power-ups enable the production of high-performance sensors at low compute resources and reasonable prices. Thus, relatively sparse deployments of VigilAir sensors can cover hundreds of square kilometers, while no other system or technology available today provides such detailed drone information at these large distances and areas, at such reasonable costs. This wide coverage can enable the easy and practical dissemination of large amounts of detailed drone related information, e.g. based on a SaaS model, to multiple customers at different localities. In addition, VigilAir's information, because of its wide-coverage, can be fed in-

to current manned-aviation ATC systems, enabling the peaceful cohabitation and coordinated operation of manned and unmanned flight frameworks.

Urban Operation

Urban environments are extremely complex to perform drone monitoring in – dense landscape of tall buildings, lawful limitations and regulations hindering the operation of transmitting solutions, endless numbers of radio transmitters of multiple types etc. VigilAir is quite unique in its ability to operate flawlessly in dense urban environments and has been successfully deployed and tested in challenging locations such as Manhattan and Singapore City. With the expected central role of urban drone operations, VigilAir can be central to providing reliable and accurate urban situational awareness to support UTM frameworks. Being a passive & non-transmitting system, VigilAir meets all relevant regulations regarding deployment of technologies in urban and highly populated areas.

Independent and Reliable Positioning

Drones can lose their self-positioning capability when flying in dense urban zones, subjected to GNSS jamming or spoofing and when tampered with. When

that happens, the drone cannot report its own position, it is left to the very limited onboard DAA capabilities and the UTM system loses the ability to manage it. VigilAir is an accurate, reliable and independent source of drone geolocation information, since it does not rely on drone self-reporting, flight path registration or local GNSS availability, as it makes use of the “raw” drone RF transmissions, regardless of whether their transmission content has been tampered with (as, e.g., in a tampered drone purposefully reporting a wrong location). VigilAir will also provide reliable geolocation information in cases of a malfunction in the drone positioning determination mechanism, as well as when it is being jammed or spoofed.

Rogue Drone Operator Geolocation

VigilAir is unique in its ability to provide geolocation and tracking information on drone operators, homing in on the RF up-link transmission emanating from the drone controllers. With the extreme level of RF geolocation accuracy only VigilAir can provide, operator location will in most scenarios be available, enabling the apprehension of the operator when needed. This geolocation information provides a totally different ability to mitigate drone-related mishaps and events at

their source – the clueless, careless and criminal operators who are not “playing” by the cooperative rules envisioned as the base for future UTM systems and frameworks. VigilAir will therefore generate effective deterrence of malefactors, as visibility and enforcement are enabled not only for drones but also for their operators.

Additional Geolocation Possibilities

VigilAir’s proprietary geolocation technology can be aimed at additional transmission types, not only the command & control, telemetry and video links operating between an operator and his drone. Thus, if any type of transponder, beacon or electronic “license plate” for drones is ever mandated or regulated, VigilAir will be able to geolocate these transmissions as well. This will provide additional geolocation and tracking capabilities, where VigilAir’s data, generated from “raw” RF reception & analysis, will be resistant to any tampering and spoofing performed on these mechanisms.

Enabling an informed, Surgical and Proportional Response

While the technologies enabling current day Air Traffic Control (ATC) systems used for commercial manned aviation are in effect absent from the drone domain (e.g. because of small size present-

ing a real challenge to radars, no transponder regulation etc.), VigilAir’s extremely high accuracy provides ATC-like capabilities for drone tracking and geolocation. With its high-clarity situational awareness picture, coupled with a zero-rate of false alarms, VigilAir can enable the thoughtful and knowledgeable response to a drone-related emergency. As civilian UTM drone management and enforcement activities attempt to be more localized, contained and controlled than a military-type response, VigilAir’s extremely high accuracy enables a highly focused response to dynamically evolving drone events, maintaining minimal collateral effects.

Summary

VigilAir, from Vorpai Ltd., is a unique RF-based solution enabling highly sensitive detection and highly accurate geolocation & tracking of commercial drones (both cooperative and non-cooperative) and their operators, over very large areas and in dense urban environments. VigilAir is unique in its ability to create, in real time, an acute drone situational awareness picture of cooperative and non-cooperative drones over wide areas.

Future UTM frameworks, while based on cooperative pre-planning, will also require real-time visibility, enforcement and regulation of mass drone activities over large geographical areas. VigilAir can and should be integrated as a core module in future UTM systems and frameworks, since it can provide; and over very wide areas, highly accurate, real-time, unique, independent and reliable mass drone information situational awareness, even when facing purposeful malicious activities. Easily deployed with low TCO over existing infrastructure grids, VigilAir's information will enable the localized, focused and controlled management, handling and resolution of drone related events and emergencies. Usage of VigilAir will thus enhance the reliability, safety and security of UTM systems, and will effectively contribute to the widespread adoption of large-scale commercial drone activities and operation.

About Vorpai

Vorpai Ltd., is an Israel-based boutique technological powerhouse focusing on cutting edge signals analysis products and solutions. Aided by years long experience in military-grade Signals Intelligence (SIGINT), Vorpai is able to successfully design and deploy advanced and highly accurate geolocation solutions. Leveraging a wide array of inhouse capabilities, Vorpai builds its systems with optimal integration of hardware and software to provide best-of-breed RF-based geolocation solutions. Vorpai operates globally in the Aviation, Military and HLS, Critical Infrastructures and UAS Traffic Management (UTM) markets



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