*Review*

# Considerations for Unmanned Aerial System (UAS) Beyond Visual Line of Sight (BVLOS) Operations

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**ABSTRACT:** This paper, intended for expert and non-expert audiences, evaluates the technical and regulatory requirements for Unmanned Aerial Systems (UAS) to operate beyond visual line of sight (BVLOS) services. UAS BVLOS operations have the potential to unlock value for the industry. However, the regulatory requirements and process can be complex and challenging for UAS operators. The work explored the BVLOS regulatory regime in the UK, Europe and the US and found similarities in process and requirements covering themes like Detect and Avoid (DAA), Remote identification and Reliable Connectivity. A unifying goal across these jurisdictions is to operate BVLOS safely and securely in non-segregated airspace. However, operating BVLOS in segregated airspace as the default or routine mode could accelerate approval and adoption. The paper reviewed existing challenges, highlighting Coverage, Capacity and Redundancy as critical for UAS BVLOS Operations. The work also highlighted the crucial role of Non-terrestrial Network (NTN) assets like Satellites and HAPS (High Altitude Platform Station) since terrestrial networks (not optimised for aerial platform coverage) may not be reliable for BVLOS connectivity.

**Keywords:** BVLOS; UAS; UAV; Drones; Autonomous

## 1. Introduction

Drones are rapidly gaining widespread acceptance and are increasingly utilised in our industrial, social, and digital realms to address various challenges, such as agriculture, traffic management, logistics, last-mile delivery, power line inspection, connectivity, and numerous other sectors [1,2]. According to GSMA, drones are projected to contribute to a 1.6% increase in the Gross Domestic Product (GDP) in the UK alone by 2030, while PwC estimates a £45 billion contribution over the same period [3,4]. This global trend is evident and expanding across various industries and applications. Drone startups and technology firms are driving innovation and solutions on a global scale. On the regulatory front, continuous efforts are underway to establish appropriate oversight and support, aiming to strike a balance between safety and security on the one hand and fostering innovation on the other. The regulatory landscape of the drone industry will play a pivotal role in determining its short- and long-term viability, particularly from a commercial perspective. Integrating drones into the existing manned airspace is a crucial challenge. Presently, most drones operate in uncontrolled or restricted airspace, reducing the likelihood of incidents with other airspace users.

Additionally, regulating the increasing drone traffic alongside aeroplanes, helicopters, and other aerial systems is a significant challenge. A recent publication by one of the authors [5] provides some background and context for drone use cases, defining autonomy in multi-drone systems and Beyond Visual Line of Sight (BVLOS) operations, laying out the backdrop on which this current paper is framed. This paper, among other objectives, is positioned to contribute to the ongoing conversation around the technical and regulatory frameworks for civil BVLOS operations.

Safe and secure BVLOS operations can unlock value for Unmanned Aerial System (UAS) services. Visual Line of Sight (VLOS) operations, the technical "opposite" of BVLOS operations, will be introduced to set the context. According to the International Civil Aviation Organisation (ICAO), VLOS is a straight line along which the remote pilot has a clear view of the Unmanned Aircraft (UA) [6]. The UK Civil Aviation Authority (CAA) considers VLOS a

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type of UAS operation that requires the remote pilot to maintain unaided visual contact with the UA, monitoring the aircraft's position, orientation, and surrounding airspace at all times [7]. VLOS operation is predicated on the remote pilot's requirement to remain in visual contact with the UA being flown. These requirements put geographical and range constraints on the operational profiles of UAVs (see Figure 1). The reason for this restriction is to assure the safety and security of the public, air traffic and other assets around the immediate vicinity of the unmanned aircraft.

In some cases, Extended Visual Line of Sight (EVLOS) mode is used, which involves adding human observers along the trajectory of the UA, essentially acting as the extended "eyes" of the remote pilot. Overall, EVLOS operations do not significantly extend the range of operations with the disadvantage of increasing operational overheads. VLOS and EVLOS operations do not permit easy scaling of the services or use cases possible with UAS applications. BVLOS operation, according to the European Aviation Safety Agency (EASA), is any UAS operation that is not conducted under VLOS conditions, which essentially requires the remote pilot to maintain continuous unaided visual contact with the UA [8]. It includes all existing and potential UAS operations where the aerial vehicle is out of sight of the remote pilot [9]. Under BVLOS mode, a remote pilot can operate the pilot from another geographical region. This possibility is a game changer, potentially leading to operational and business breakthroughs. The question of technological readiness, both in terms of efficiency and reliability, is the next factor to consider.

At this stage of the evolution of the UAS or Unmanned Aerial Vehicle (UAV) operations, it is evident that the relaxation of regulatory restrictions is not imminent. BVLOS operations are critical for autonomous UAS use cases, but regulators are cautious about approving routine implementation. It is understandable why regulators are so cautious (even slow) and methodical with approvals or relaxing requirements. The paper will examine the technological and policy ramifications of the current journey to developing and standardising the UAS BVLOS regime across jurisdictions. It will be important to establish if the technology is ready and if policy is lagging.

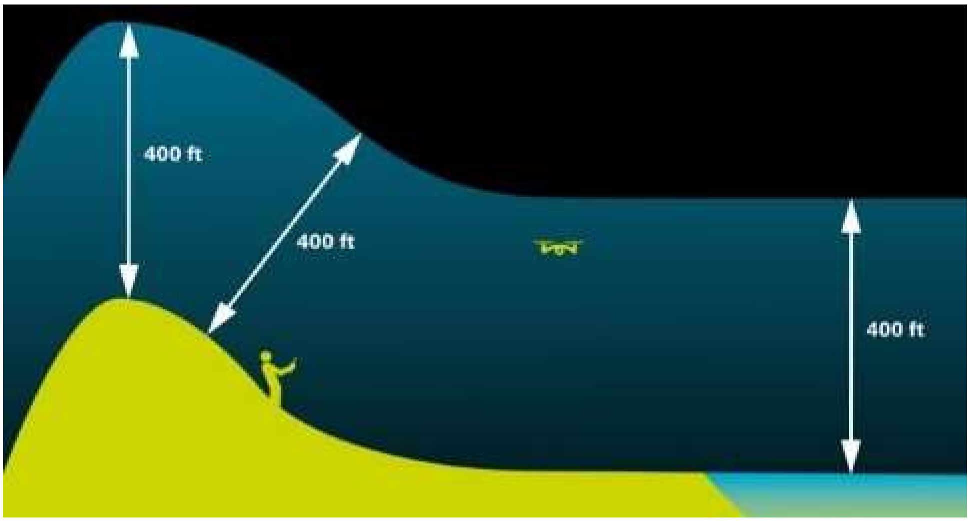

**Figure 1.** VLOS Operating Heights—400 ft (120 m) [7].

The main contributions of this review paper are outlined as follows;

- An overview of current BVLOS regulatory requirements.
- Review of technological progress and gaps flowing from the BVLOS regulatory requirements.
- Overview of other key factors required to achieve successful BVLOS technology accreditation across jurisdictions.
- Proposals/considerations to mitigate BVLOS regulatory and technical challenges.

The rest of the paper is arranged as follows: Section 1 introduces the concept of BVLOS and provides some regulatory and technical context for the work. Section 2 reviews the regulatory framework for UAS BVLOS operations across some jurisdictions. Section 3 addresses the technical capabilities essential for UAS BVLOS operation. In Section 4, the authors contribute ideas and considerations for addressing existing issues to support ongoing consultations. Finally, Section 5 concludes the work and reiterates salient points.

## 2. The Regulatory Framework for UAS BVLOS Operations

The UAS regulatory environment determines the technological and operational boundaries or parameters that UAS operators must abide by. These regulatory guidelines and requirements vary with jurisdiction and introduce complexity when planning services across jurisdictions. The BVLOS regulatory environment is still evolving as authorities are examining the safest and most secure ways to manage the approval of this mode of UAS operations. Due to the plethora of regional aviation and UAS regulatory organisations and the reality of the different rates at which they have progressed on these issues, this paper will limit the analysis to three jurisdictions: the United Kingdom, the European Union, and the United States.

### 2.1. UK CAA BVLOS Regulation

Flying or operating under BVLOS conditions in the UK is not prohibited or restricted, but permissions must be sought from and given by the UK CAA on a case-by-case basis [10]. BVLOS operations in uncontrolled airspace are required by regulation to operate separated or segregated from other traffic [11]. In this segregation mode, establishing a Temporary Danger Area (TDA) or Permanent Danger Area or controlled airspace is needed. However, the process of obtaining the necessary permissions and the accompanying documentation is significant. The underlying regulatory philosophy for UAS operations generally focuses on the impact on third parties [7]. The UK CAA will, therefore, demand more effort or proof as the risk for third parties increases. It is within this context of the third-party impact that BVLOS operations are evaluated. BVLOS operations are not permitted in non-segregated airspace until certain levels of safety can be achieved through highly capable Detect and Avoid (DAA) techniques or solutions. DAA in UAS operations is what See and Avoid (SAA) is to manned aircraft operations. In summary, the UK CAA requires that BVLOS operations have technical capabilities to satisfy DAA requirements or resort to operational mitigation techniques like airspace segregation [7].

### 2.2. FAA BVLOS Regulation

The FAA also requires that UAS operations be conducted at the strictest levels of safety. Flying BVLOS is prohibited by the FAA’s Part 107 rules for commercial drone operations [12]. However, the FAA provides about two ways to deal with this prohibition, which could be complicated and lengthy. One way is to obtain a Part 107 BVLOS Waiver from clause 107.31—Visual Line of Sight Aircraft Operation [12]. This waiver allows flying a UAS beyond the ability of unaided vision where determining position, altitude, attitude, and movement is not possible. Another way around the BVLOS restriction is to apply for a Part 135 certificate, which permits small drones to be used for the commercialisation of parcel delivery beyond visual line of sight.

The FAA is in the process of reviewing recommendations of the UAS BVLOS operations Aviation Rulemaking Committee (ARC) and soliciting public comments as it considers the expansion of BVLOS operations [13].

### 2.3. EASA BVLOS Regulation

EASA has defined three categories of UAS operations, “open”, “specific”, and “certified”, depending on the level of risk involved [8]. The “specific” and “certified” categories require prior authorisation or certification before UAS operators can operate in these categories due to the level of risk involved. The “open” category does not need prior operational authorisation or declaration by the operator. However, EASA specifies BVLOS as an example of UAS operations in the ”specific” category and, therefore, requires prior authorisation [8]. To operate under the “specific” or “certified” categories like BVLOS, EASA requires the UAS to be operated within a defined geographic zone or safety buffer (see Figure 2). This restriction or confinement to a well-defined geographical zone or operating area mitigates conflict with other aircraft and third parties. In addition to geographical deconfliction requirements, risk assessment, training and specific technical capabilities are also considered. It is important to mention that the EASA uses the risk assessment methodology known as SORA (Specific Operations Risk Assessment) to classify the risk posed by a drone flight.

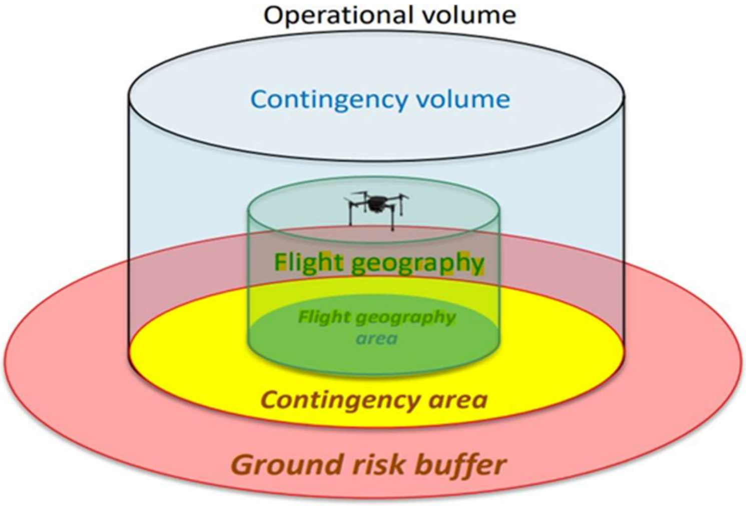

**Figure 2.** EASA's UAS operations Safety Buffers [8].

## 3. Technical Capabilities Essential for UAS BVLOS Operations

The BVLOS regulations covered in the previous section have largely addressed BVLOS in some segregated operational scenarios, though SORA regulates operations in non-segregated airspace. This approach is logical and ensures that UAS operations can be conducted more safely as regulators and operators figure things out. However, the ultimate destination is to deploy BVLOS operations in non-segregated scenarios. Achieving this will demand some technical capabilities that will provide iron-clad guarantees on the safety case for UAS operations. For instance, sensing and avoiding air traffic, and maintaining safe separation distance is very critical for BVLOS operations and airspace integration [14]. Some of the key technical challenges and capabilities needed to achieve full non-segregated BVLOS operations are discussed further below.

### *3.1. Detect and Avoid Capability*

A fundamental requirement for safe UAS operations is the capability of the UAS to detect and avoid conflicting traffic and any other hazards. Any adopted technical solution must be able to equip the UAS itself with the capability to detect a hazard, maintain safe separation and initiate collision avoidance if needed [10]. There is no single solution for DAA, and it is largely still an ongoing challenge. It is expected that a typical solution will involve a combination of different technical and operational approaches depending on the specifics of the mission. The UK CAA approaches the DAA solution more like an ecosystem (a framework) of various functions and phases (see Figure 3) [15]. The key five functions, as shown in Figure 3, are Detect, Inform, Decide, Avoid and Strategic Mitigation. Operators and innovators can decide how to develop or apply technological solutions to satisfy these functions or requirements. Relaxing restrictions on BVLOS operations depends on the emergence of robust, reliable, safe DAA capabilities and solutions.

**Figure 3.** DAA Ecosystem [15].

### *3.2. Remote Identification*

Remote Identification (Remote ID), also known as “digital license plates for drones”, provides a standardised approach for identifying UAVs and their pilots [16]. Identification procedures for manned aircraft are well established but not easily adaptable or transferable to unmanned aircraft contexts. It involves wirelessly broadcasting a standardised set of information needed to uniquely identify and account for the UAS as a whole. The FAA, for instance, requires a minimum set of message elements to include the identity of the UAV (serial number and session ID), UAV and control station coordinates, UAV velocity, control signal timestamps and emergency status indicator [17]. Every UAV manufacturer will have to figure out how to integrate this capability in UAS products to meet these minimum requirements. The FAA will be enforcing the remote ID requirement from 16 September 2023, for all unmanned aircraft within the United States airspace (unless authorised otherwise). Generally, and across different jurisdictions two technical approaches have been proposed for meeting remote ID requirements [18];

1. Broadcast Remote ID: The UAV broadcasts identification messages directly and without restriction within its immediate territory.
2. Network Remote ID: The UAV sends the required identification information to a third-party service provider who makes the information available based on legitimate and authenticated requests.

The Broadcast Remote ID seems to have received more acceptance based on the minimum technical and management infrastructure needed. Compliance with Broadcast Remote ID under FAA rules can be met either through acquiring UAVs with in-built remote ID capabilities or retrofitting existing UAVs with add-on hardware/software [17]. The third option which does not require Remote ID Broadcast is flying within FAA recognised identification area (FRIA). Remote ID capabilities are an essential requirement for BVLOS operations and will potentially improve the safety case and risk mitigation requirements.

### *3.3. Reliable Connectivity & Coverage*

UAS BVLOS operations require reliable connectivity and coverage to operate safely and securely throughout any assigned mission. High link uptime and very low latency communications are an absolute requirement for BVLOS operational scenarios. BVLOS operations need reliable communication and datalink channels transmitting and receiving control, payload information and mission-relevant data [18]. Possible connectivity options can be cellular, satellite or unlicensed RF. In partially or fully autonomous UAS scenarios, real-time data needed for decision-making purposes cannot be exchanged unreliably. As the UAS platforms transverse the airspace coverage by either cellular or more realistically satellite links must be assured. As 5G evolves, UAV connectivity and coverage is a strong use case consideration. However, connectivity and coverage solutions must meet high availability and reliability targets to guarantee the safety and security threshold demanded by regulation. A lot of the functions outlined in the DAA ecosystem in the previous section rely so much on the connectivity and coverage factor. In addition to the high availability requirements, the security of the communication links will be equally as important. The technical hurdles to meet non-segregated BVLOS operations are significant but not insurmountable.

### *3.4. Reliable and Safe Autonomy*

The ultimate goal for UAS operations is to have fully autonomous drones that can navigate and execute missions with little or no human intervention. With the advances in artificial intelligence (AI) and machine learning, fully autonomous drones are within the technology horizon. However, the challenge with full autonomy and the application of AI for UAS operations is the regulatory hurdle. Fully autonomous UAS operations must satisfy compliance requirements and complicated approval processes. Theoretically speaking-, advances in AI will keep improving the autonomous capacity of modern drones and reducing the barrier to fully autonomous operations. The challenge, however, is how to convince regulators that UAS autonomy algorithms are reliable and safe. For instance, self-driving cars with less complicated regulatory and technical environments have struggled to meet the threshold requirements and have had several high-profile incidences in recent years. BVLOS operations can operate at a lower threshold of autonomy with some level of human input, though fully autonomous operations hold the most promising operational and business considerations.

## 4. Considerations for Accelerating BVLOS Operations

In this section, the authors will lay out considerations for accelerating the approval and deployment of BVLOS operations. BVLOS operations are fundamental to unlocking the value in UAS implementation across various sectors and use cases. As indicated in the UAS operations pyramid (see Figure 4), value, risk and regulation increase as UAS operations evolve from VLOS to BVLOS. Commercial success will depend on how much the cost of these various elements can be offset effectively and efficiently. Regulatory requirements are quite steep because of the risk element, and value can only be fully realised when UAS operations can guarantee safety and security across all layers. Some key considerations will be highlighted in the following subsections to address concerns evaluated earlier.

**Figure 4.** UAS Operations Pyramid.

### *4.1. Failsafe Connectivity*

BVLOS operations are contingent on reliable connectivity and coverage, as outlined earlier. Due to the mission-critical nature of some UAS operations, command and control (C2) and other critical messages must be delivered reliably and securely. The regulators are always keen to establish how UAS operators will guarantee the availability of critical links throughout the flight. Failsafe connectivity is one way of addressing the requirements of ensuring the availability of reliable communications for BVLOS operations. This connectivity consideration consists of three main elements: Coverage, Capacity and Redundancy, as shown in Figure 5.

- Coverage: BVLOS operations cannot be successful if coverage by either terrestrial or non-terrestrial assets is unavailable or inadequate. UAS coverage requirements cannot be adequately provided by terrestrial networks due to specific technical factors. For instance, terrestrial networks are specially designed for ground-based nodes or devices and are not suitable or optimised for aerial-based UAS operations. The UAS platforms are essentially served by the sidelobes of the down-tilted base station (BS) antennas, which is less than ideal [19]. The mobile generation of the terrestrial-based system (4G, 5G or yond) will have minimal impact due to this limitation. Non-terrestrial network (NTN) infrastructure like satellites and HAPS are most suited to support the coverage requirements for UAS operations. Connectivity and coverage maps that provide UAS operators with accurate coverage information before the UAVs are deployed will be helpful.
- Capacity: The network capacity available for the UAS for its various control and payload information transmission and reception is an important resource requirement. Cellular networks could potentially provide data rates of about 10 gigabits per second (Gbps), which is theoretically sufficient for most UAS operational needs [18]. It is projected that 5G networks will have latency values as low as one (1) millisecond, which is suitable for BVLOS operations. However, the challenge is that terrestrial networks, which are more capacity-dense, may not serve UAS operations optimally. Another capacity-related issue is how the network manages congestion or a sudden demand for capacity for various reasons. It may not be practical or even permissible to throttle or deprioritise any UAS platform to manage capacity issues.

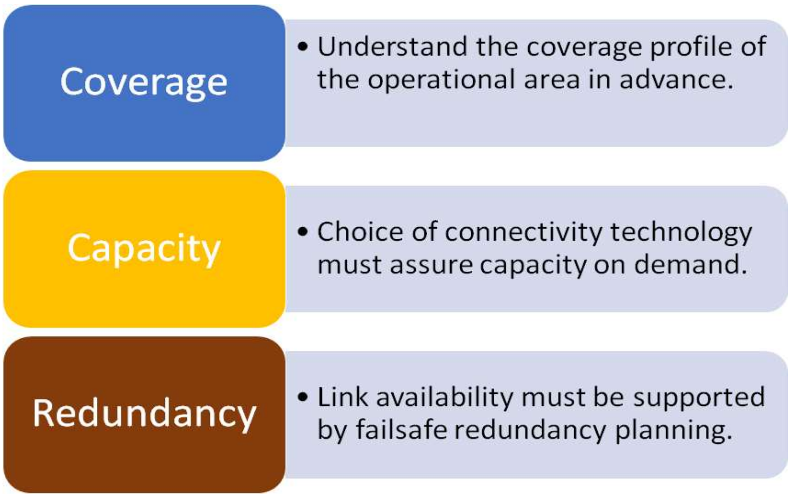

**Figure 5.** BVLOS Connectivity Framework.

On the contrary, BVLOS and other mission-critical UAS services will require capacity on demand for safe and reliable operations.

- Redundancy: The reliability of BVLOS operations can only be satisfactory if link failures or network outages are mitigated in such a way that downtime is almost zero. Connectivity for UAS operations should be designed to have multiple layers of redundancy to guarantee maximum uptime. The redundancy planning being proposed is such that AI algorithms can sense or predict connectivity issues and initiate no-fail switching across redundant and backup links. Some UAV vendors have integrated cellular bonding capabilities into their products as part of the redundancy fabric. Cellular bonding involves combining several carriers or cellular connections for redundancy and bandwidth aggregation [18].

### *4.2. Segregate, Mitigate & Integrate (SMI Loop)*

The current posture with BVLOS operations considers the approval and deployment in non-segregated scenarios as the ultimate trajectory for the industry. This trajectory also triggers the pressure to deal with UAS integration challenges with conventional traffic both from a technical and regulatory perspective. However, the authors consider it safer and more pragmatic to manage BVLOS operations and its approval process as a loop (see Figure 6).

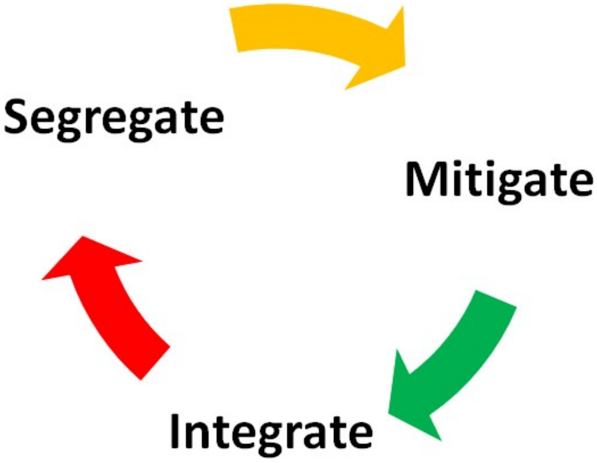

**Figure 6.** The SMI Loop.

Under this consideration, flying in segregated airspace should be the default option unless the mission or use case dictates otherwise. Regulators will only consider approving UAS BVLOS operations in the “Integration” phase (operating in non-segregated airspace) if there is justification for it. The “Mitigation” phase is like a waiting phase where the UAS operator who intends to operate in a non-segregated mode deals with issues highlighted by the approving authority. A UAS operator that fails audit or other compliance requirements at the “Integrate” phase will have to be downgraded to the “Segregation” mode. This approach will minimise complexity and delays in the process or approach regulators are currently adopting, driven by the need to err on the side of caution. The authors are proposing a regulatory regime where UAS operators are accepted into the “Segregate” phase with minimal regulatory hurdles. In this phase, the UAS operator is segregated (assigned airspace or corridor to operate). During the “Segregate” phase, observed risks are highlighted for mitigation. If such an operator, because of their use case or mission, decides to be elevated to the “integrate” phase, then all risks observed in the “Mitigate” phase must be addressed. Only UAS operators that scale the “Mitigate” phase can be considered for the “Integrate” phase. Operating in the “Integrate” level or phase is not perpetual; a UAS operator can be downgraded to the “Segregate” phase if they perform below a specified safety or security threshold. This approach could reduce regulatory bottlenecks and unlock innovation and value.

In summary, operating in segregated airspace or corridors should be the default operating model. For instance, the UK’s drone superhighway, a 165-mile (265-kilometre) drone corridor being developed, will provide segregated airspace for UAS operations [4]. This project will significantly reduce the regulatory burden on individual operators as the dedicated corridor will be equipped to centrally manage drone traffic with advanced sensors and protocols. “Integration” or operating in non-segregated airspace should be the exception supported and justified by the mission or use case.

### *4.3. Mission Defined Autonomy (MDA)*

Mission Defined Autonomy (MDA) ensures that UAS operations align with the level of autonomy sufficient for the mission or function. Fully autonomous UAS platforms are desirable, and research and industry efforts are working towards this. The idea is to eliminate unnecessary delays for regulatory approvals due to over-engineering a system beyond its functional use or application. If VLOS operations are sufficient for a specific use case, then that should be the guiding principle. BVLOS operations and the autonomous capabilities that may be required should be guided by the use case or mission. This is purely an approach informed by the need to overcome regulatory delays and bottlenecks. The consideration or focus of this section is how to address or manage regulatory hurdles to achieve accelerated BVLOS operations. The authors propose that autonomy should be driven by function or, more specifically, the mission. Full autonomy should only be sought or applied when the mission justifies such capability. UAS operators should ensure that UAS use cases and applications are aligned with the appropriate functional autonomy required. This approach will reduce regulatory hurdles and facilitate a smoother approval process.

## 5. Conclusions

UAS BVLOS operations have the potential to unlock value for the industry. It will enable UAS operators to extend the range and reach of their services and scale easily. However, the current regulatory regime is very cautious about approving BVLOS operations for obvious reasons. The risks posed by flying or operating under BVLOS conditions are quite significant, and regulators are mindful of this. FAA, UK CAA, and EASA BVLOS regulations reflect this cautiousness, which also risks stifling the growth and innovation of the industry. Certain technical and operational issues central to the BVLOS approval requirements were highlighted. At this moment, the regulators in the referenced jurisdictions are still soliciting input on how best to manage BVLOS requirements and approval. This paper seeks to contribute some ideas and considerations as part of the consultation process. The authors highlighted some considerations for Connectivity and Coverage, BVLOS approval process and Autonomy. One key recommendation is to make operating in segregated airspace the default operating model and encourage innovation around this. Operating in non-segregated airspace should be minimal and justified by the mission or use case. This approach could revolutionise the approval process and unlock the huge potential inhibited by complex and laborious approval regimes.

## Author Contributions

The contributions of the authors are as follows; Conceptualisation, O.A.; Methodology, O.A. and A.K.N.; Investigation, O.A.; Resources, A.K.N.; Data Curation, O.A.; Writing—Original Draft Preparation, O.A.; Writing—Review & Editing, O.A., A.K.N. and J.C.B.; Supervision, A.K.N.; Project Administration, O.A. and J.C.B.

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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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