# Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization

## Edition 2

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# Definitions

*Note.— The definitions contained herein are used in the context of this document. Except where indicated, they have no official status within ICAO. Where a formally recognized ICAO definition is included for convenience, it is noted with an asterisk (*). Where a term is used differently from a formally recognized ICAO definition, it is noted with the symbol **.*

***Aeronautical information service (AIS).**** A service established within the defined area of coverage responsible for the provision of aeronautical data and aeronautical information necessary for the safety, regularity and efficiency of air navigation.

***Aircraft.**** Any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface.

***Air traffic control service.**** A service provided for the purpose of:

a) preventing collisions:

- between aircraft, and
- on the manoeuvring area between aircraft and obstructions; and

b) expediting and maintaining an orderly flow of air traffic.

***Air traffic management (ATM).**** The dynamic, integrated management of air traffic and airspace (including air traffic services, airspace management and air traffic flow management) – safely, economically and efficiently – through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions.

***Air traffic management (ATM) system.**** A system that provides ATM through the collaborative integration of humans, information, technology, facilities and services, supported by air and ground- and/or space-based communications, navigation and surveillance.

***Air traffic service.**** A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service).

***C2 Link.***** The data link between the remotely piloted aircraft and the remote pilot station for the purpose of managing the flight.

***Detect and avoid.**** The capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action.

***Geofence.*** A virtual three-dimensional perimeter around a geographic point, either fixed or moving, that can be predefined or dynamically generated and that enables software to trigger a response when a device approaches the perimeter (also referred to as geoawareness or geocaging).

***Operator.**** A person, organization or enterprise engaged in or offering to engage in an aircraft operation.

*Note.—* In the context of unmanned aircraft, an aircraft operation includes the unmanned aircraft system.

***Prohibited area.**** An airspace of defined dimensions, above the land areas or territorial waters of a State, within which the flight of aircraft is prohibited.

***Remotely piloted aircraft (RPA).**** An unmanned aircraft which is piloted from a remote pilot station.

***Remotely piloted aircraft system (RPAS).**** A remotely piloted aircraft, its associated remote pilot station(s), the required C2 Link and any other components as specified in the type design.

***Restricted area.**** An airspace of defined dimensions, above the land areas or territorial waters of a State, within which the flight of aircraft is restricted in accordance with certain specified conditions.

***Segregated airspace.**** Airspace of specified dimensions allocated for exclusive use to a specific user(s).

***Unmanned aircraft system traffic management (UTM).*** A specific aspect of air traffic management which manages UAS operations safely, economically and efficiently through the provision of facilities and a seamless set of services in collaboration with all parties and involving airborne and ground-based functions.

***Unmanned aircraft system traffic management (UTM) system***. A system that provides UTM through the collaborative integration of humans, information, technology, facilities and services, supported by air, ground or space-based communications, navigation and surveillance.

***Unmanned aircraft system (UAS).**** An aircraft and its associated elements which are operated with no pilot on board.

***Visual line-of-sight (VLOS) operation.**** An operation in which the remote pilot or RPA observer maintains direct unaided visual contact with the remotely piloted aircraft.

# Abbreviations

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| AGL | Above ground level |
| AIP | Aeronautical information publication |
| AIRAC | Aeronautical information regulation and control |
| AIS | Aeronautical information service |
| AIXM | Aeronautical information exchange model |
| ANS | Air navigation service |
| ANSP | Air navigation service provider |
| API | Application programming interface |
| ATC | Air traffic control |
| ATM | Air traffic management |
| BVLOS | Beyond visual line-of-sight |
| CAA | Civil aviation authority |
| CNS | Communications, navigation and surveillance |
| E-ID | Electronic identification |
| FIMS | Flight information management system |
| FIS | Flight information service |
| FIMS | Flight information management systems |
| FSS | Fixed satellite service |
| GIS | Geographic information system |
| GNSS | Global navigation satellite system |
| ICAO | International Civil Aviation Organization |
| IFR | Instrument flight rules |
| ITU | International Telecommunication Union |
| NOTAM | Notice to airmen |
| RFI | Request for information |
| RCP | Required communication performance |
| RNP | Required navigation performance |
| RSP | Required surveillance performance |
| RPA | Remotely piloted aircraft |
| RPAS | Remotely piloted aircraft system |
| SWIM | System wide information management |
| UA | Unmanned aircraft |
| UAS | Unmanned aircraft system(s) |
| UAS-AG | UAS advisory group |
| USP | UTM service provider |
| UTM | UAS traffic management |
| VFR | Visual flight rules |
| VLOS | Visual line-of-sight |
| VTOL | Vertical take-off and landing |
| WRC | World Radiocommunication Conference |

# Foreword

Over the last ten years, technological development in the unmanned aircraft (UA) industry has disrupted aviation, and introduced enhanced capabilities at an unprecedented pace. As a result, States and regulators have received an increasing number of applications for access to low-level airspace, where the operations of manned aircraft are generally limited or restricted. At the current pace, civil unmanned aircraft system (UAS) operations are expected to surpass the number of manned aircraft operations in the near future. Air navigation service providers (ANSPs) anticipate that such operations will include those that are fully contained in either controlled or uncontrolled airspace, and those that transit across their boundaries.

The pace and off-the-shelf emphasis of technological advancement poses a significant challenge to the timely development of standards. In particular, the lack of stability in aircraft design and equipage as well as the use of non-traditional aviation-related communications and navigation technologies renders any attempt to use traditional methods of certification and operational approval impractical. To meet demand, States and regulators are encouraged to be innovative and proactive in facilitating and approving such proposals; however, this is leading to a lack of harmonization that may impact safety, security, the environment, system reliability and economic efficiency.

The UAS traffic management (UTM) concept was first proposed in 2016 by members of State research organizations and industry to support the real-time or near-real-time organization, coordination, and management of UA operations, including the potential for multiple beyond visual line-of-sight (BVLOS) operations.

Through UTM, it is envisaged that civil aviation authorities (CAAs) and ANSPs, to the extent that they are involved, will be able to make real-time information regarding airspace constraints and the intentions of other aircraft available to UAS operators directly or through a UTM service provider (USP). The UAS operator would then be responsible for managing its operations safely within these constraints, without receiving positive air traffic control (ATC) services from the ANSP. The primary means of communication and coordination between the ANSP(s), UTM services providers, operators and other stakeholders may be through a distributed network of highly automated systems via application programming interfaces (APIs), and not between pilots and air traffic controllers via voice communication.

Although some UAS are unable to comply with the *Convention on International Civil Aviation* (Doc 7300), signed at Chicago on 7 December 1944 and amended by the ICAO Assembly, at the 39th Session of the ICAO Assembly, it was requested that ICAO address, as a matter of urgency, the increasing number of UA operating in low-level airspace that might conflict with manned aviation, and develop a global baseline of provisions and guidance material for the proper harmonization of UAS regulations that remained outside the international instrument flight rules (IFR) framework. As a result, ICAO has assembled industry partners, at its annual DRONE ENABLE Symposiums, to assist in providing direction and guidance in support of harmonizing UAS regulatory activities throughout the Member States. Since UTM as a concept is already under development, a common agreement on its framework and principles is essential to ensuring global harmonization and interoperability. Accordingly, ICAO is supporting States, UAS industry leaders and academic and aviation professionals in the development of a common agreement on the framework for UTM that will remain consistent with the principles of the Convention.

Notwithstanding potentially disparate rules and regulations, a lack of guidance material or limited consensus on best practices or standards, the Preamble to the Chicago Convention (1944) remains valid:

> WHEREAS the future development of international civil aviation can greatly help to create and preserve friendship and understanding among the nations and peoples of the world, yet its abuse can become a threat to the general security; and WHEREAS it is desirable to avoid friction and to promote that cooperation between nations and peoples upon which the peace of the world depends; THEREFORE, the undersigned governments having agreed on certain principles and arrangements in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically; Have accordingly concluded this Convention to that end.

*Note.— In this guidance material, the term "unmanned aircraft" or "UA" is intended to refer to UA that will primarily operate within the UTM framework. It does not include those UA, including remotely piloted aircraft (RPA), operating within the traditional air traffic management (ATM) system.*

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# Scope

This document is intended to provide a framework and core capabilities of a “typical” UTM system to States that are considering the implementation of a UTM system. Any such UTM system must be able to interact with the overarching ATM system without negatively affecting the safety or efficiency of the existing ATM system. A common framework is needed to facilitate harmonization between UTM systems globally and to enable industry, including manufacturers, service providers and end users, to grow safely and efficiently without disrupting the existing manned aviation system. Specifically, this document may be used by States to develop a UTM system that provides the following benefits:

- continued safety of all air traffic, manned and unmanned;
- safety of persons on the ground;
- complex low-level UA operations;
- ongoing support of technological advancements;
- evaluation of security and environmental risks; and
- provision for a global, harmonized framework for low-level UTM.

This framework is not intended to propose or endorse any specific UTM system design or technical solutions to address the UTM challenge; instead, its aim is to provide an overarching framework for such a system. Accordingly, the following sections propose a common set of guiding principles and enabling actions.

Initial assessment parameters include the overall effectiveness, safety and efficiency of the UTM system; registration and identification systems; communications compatibility between UTM, ATC and potentially manned aircraft; detect and avoid (DAA) capabilities; geofencing-like systems (benefits, constraints, restraints, etc.); interoperability (with other systems and other States); adaptability of the architecture; infrastructure performance requirements (including reliance on existing infrastructure); frequency spectrum (availability, suitability, security, etc.) and cybersecurity. Like the technology, this document will be updated as developments occur and system capabilities have been demonstrated.

While this document begins to explore the critical operational aspect of interoperability of certain elements of UTM with ATM, this issue will need to be further addressed in future editions of the framework. As such there are also several components of a safe and effective UTM system that may not be addressed in this edition, such as, design and certification standards of the UA and potentially stratospheric operations. It should be noted, however, that future editions of this framework may address these issues, building on the foundation established herein.

For the purposes of this guidance material, UTM is considered a separate, but potentially complementary, system to the ANSP-supplied ATM system.

# UTM Principles

*UTM is envisioned as a subset of ATM that is aimed at the safe, economical and efficient management of UAS operations through the provision of facilities and a seamless set of services in collaboration with all parties and involving airborne and ground-based functions. Such a system would provide UTM through the collaborative integration of humans, information, technology, facilities and services supported by air, ground and/or space-based communications, navigation and surveillance.*

ATM is a longstanding and well understood system for the safe and efficient management of airspace and operation of aircraft based on principles of airspace design and cooperative systems between pilots and air traffic controllers with clear roles and responsibilities. The maturing UAS sector offers many opportunities, but to be fully integrated, UA will need to coexist with manned aircraft and existing aviation systems within finite airspace resources. In doing so, safety must be paramount, and both sectors should be able to cooperate for mutual gain while avoiding undue impacts to existing airspace users or capabilities. To achieve this objective, the technology used to support UTM systems must not inadvertently degrade ATM systems (e.g. frequency spectrum saturation or jamming). Privacy, security, reliability and environmental protection are also of high public interest. UAS operations must be seen as safe, compliant and accountable if routine operations are to be accepted by the public. Each depends on the harmonization of risk- and performance-based regulations and oversight, and should include consideration of emerging technological solutions.

UTM systems are therefore envisaged to be interoperable and consistent with existing ATM systems in order to facilitate safe, efficient and scalable operations. Although system-level requirements for UTM systems have not yet been developed, core principles can be established to guide their development. There are also numerous principles in the current ATM System that remain applicable to UTM services. The following principles should be considered:

1. Oversight of the service provision, either UTM or ATM, remains the responsibility of the regulator.

2. Existing policies for aircraft prioritization, such as aircraft emergencies and support to public safety operations, should remain applicable, and practices unique to UTM should be compatible with such policies.

3. Access to the airspace should remain equitable provided that each aircraft is capable of complying with the appropriate conditions, regulations, equipage requirements and processes defined for the specific airspace in which operations are proposed.

4. The UAS operator should be appropriately qualified to perform the established normal and contingency operating procedures defined for the specific class of airspace in which operations are proposed.

5. To meet their security and safety oversight obligations, States should have unrestricted, on-demand access to UAS operators and the position, velocity, planned trajectory and performance capabilities of each UA in the airspace through the UTM system.

Where a State is considering the issuance of an operational approval for a UTM system, it must assess numerous factors, including, inter alia the following safety-significant factors: types of UA and their performance characteristics (including navigation capabilities and performance), adequacy and complexity of the existing airspace structure, nature of the operation, type and density of existing and anticipated traffic, regulatory structure, environmental considerations, the requirement for all UA in the UTM airspace volume to be cooperative, detection/separation of non-cooperative UA, management of aeronautical information service (AIS) data and geographic information systems (GIS) data applicable to the UTM airspace.

# Enabling/Complementary Activities

In addition to the key enablers of registration and identification, communications and geoawareness/geofencing discussed later in this framework, the safe operation of UAS – and BVLOS operations in particular – in a UTM system will depend on a range of supporting and enabling capabilities. UTM systems are envisaged to provide some of these capabilities but will require enabling policy and regulatory frameworks which take into account emerging technological solutions. These frameworks include, inter alia:

- An approach to regulation that is performance- and risk-based. This implies that appropriate standards are put in place. The UTM regulatory framework should be consistent with the rules for UAS operations and the technical requirements for UAS. Responsibilities of the various actors should be clearly spelled out. Additionally, the risk-based approach should be supported by appropriate risk assessment methodologies, for both the operations and the airspace.

- A requirement for the development of and compliance with standards that address UTM-related data management to ensure that the UTM system meets an acceptable level of reliability, redundancy and fault alerting/monitoring and provides a guaranteed quality of service.

- The ability of the UTM system to accommodate UAS with varied capabilities, performance and operational requirements, based on assessment for the need of UTM, which could include a range of systems from remotely piloted UA to fully automated UA and, potentially, aircraft intended for urban mobility.

- Optimization by CAAs of common and shared airspace and the use of frequency spectrum.

- Application by CAAs or regional safety oversight organizations, of appropriate assurance standards (e.g. cybersecurity or software assurance level), where required.

- Prescribing and promoting by CAAs or regional safety oversight organizations, appropriate education, guidance and usage standards for UAS operators and USPs, where required,

- Emphasizing consistency between national and international developments and deployments of UTM systems in order to ensure interoperability and harmonization. For instance, depending on the type and location of UTM operations, a system might enable operators to submit information about a proposed flight for it to be assessed based on existing traffic demands and airspace restrictions prior to an approval or rejection being given.

- Ensuring when AIS or GIS data are used in a UTM system, that such information must be trusted, accurate and timely.

- The use by the UTM system and UA operated within that system of common horizontal, vertical and temporal reference sources compatible with the accuracy and tolerances needed for UA navigation through the airspace.

*Note.*— As it is anticipated that UTM and ATM systems will at some point coincide or overlap, the common reference sources used for UTM will need to be compatible with those used in ATM systems.

The evolution of the UTM architecture should meet the demand of the UAS community while maintaining emphasis on the criticality of safety for all airspace users (manned and unmanned) and third parties on the ground by enabling the timely introduction of the appropriate traffic density management capability to accommodate planned operations. Such an architecture would likely be predicated on the interaction and integration of these operations through information-exchange processes, avoiding direct communication with ATC, except when specifically required.

# List of Services

The UTM system can be considered as a collection of services, among other features, intended to ensure safe and efficient operations of UA within the UTM-authorized volume of airspace and which is in compliance with regulatory requirements. UAS operations may occur in uncontrolled and controlled airspace, with each type of airspace potentially requiring specific services. If UAS operations were to occur in controlled airspace, UAS operators would be required to follow the procedures and requirements for the airspace, unless an exemption or alternate procedures have been established, relieving those operating in the UTM system from the established airspace rules.

While this document does not specify technologies associated with these services, its purpose is to provide suggested types of services. These services will be based on what is required in a given geographic volume of airspace and the risk of operations and level of resiliency needed. Operational concepts have shown that these services may be provided by third-party suppliers, ANSPs or State organizations. As applicable to UAS operations in a UTM environment, these services may include, inter alia, the following:

- Activity reporting service: a service that provides on-demand, periodic or event-driven information on UTM operations occurring within the subscribed airspace volume and time (e.g. density reports, intent information as well as status and monitoring information). Additional filtering may be performed as part of the service.

- AIS: a service that enables the flow of aeronautical information/data necessary for the safety, efficiency, economy and regularity of, in this case, UAS operations.

- Airspace authorization service: a service that provides airspace authorization from the delegated State authority to the UAS operator.

- Discovery service: a service that provides users of the UTM system with information on relevant services of varying levels of capability in a specific geographical volume of airspace (e.g. suppliers of meteorological information).

- Mapping service: a service that provides terrain and obstacle data (e.g. GIS) appropriate and necessary for meeting the safety and mission needs of individual UAS operations or for supporting UTM system needs for the provision of separation or flight planning services.

- Registration service: a service that enables UAS operators to register their UA and provide any required data related to their UAS. The system should also include a query function enabling authorized stakeholders (e.g. regulators or police services) to request registration data.  See Appendix A for additional information.

- Restriction management service: a service that manages and disseminates directives (e.g. safety bulletins) and operational and airspace restrictions from the CAA or ANSP to UAS operators, including in the form of NOTAMs.

- Flight planning service: a service that, prior to flight, arranges and optimizes intended operational volumes, routes and trajectories for safety, dynamic airspace management, airspace restrictions and mission needs (this is not intended to refer to the existing manned aircraft flight planning services).

- Conflict management and separation service (Please refer to ICAO Doc 9854 Global ATM Operational Concept)

    a. Strategic deconfliction service: a service consisting of the arrangement, negotiation and prioritization of intended operational volumes, routes or trajectories of UAS operations to minimize the likelihood of airborne conflicts between operations.

    b. Tactical separation with manned aircraft service: a service that provides real-time information about manned aircraft so that UA operators remain well clear of manned aircraft.

c. Conflict advisory and alert service: a service that provides UAS operators with real-time alerting through suggestive or directive information on UA proximity to other airspace users (manned or unmanned).

d. Conformance monitoring service: a service that provides real-time monitoring and alerting of non-conformance to intended operational volumes, routes or trajectories for a UAS operator.

e. Dynamic reroute service: a real-time service that provides modifications to intended operational volumes, routes or trajectories to minimize the likelihood of airborne conflicts and maximize the likelihood of conforming to airspace restrictions, while enabling completion of the planned flight. This service would include the arrangement, negotiation and prioritization of in-flight operational volumes, routes or trajectories of UA operations while the UA is airborne.

- Tracking and location service: a service that provides information to the UAS operator and the UTM system about the exact location of UA, in real time. See Appendix A for additional information.

- Weather service: a service that provides forecast or real-time meteorological information to support operational decisions of individual UAS operators or services.

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# Gaps, Issues and Challenges

This section includes a discussion of the many gaps, issues and challenges that must be addressed to enable safe UAS operations within the UTM and ATM systems.

ANSPs anticipate that UAS operations will encompass everything from operations that are fully contained in airspace where no air traffic control services are provided (e.g. uncontrolled airspace) to those that transit across the boundary between controlled and uncontrolled airspace or that are solely operated within controlled airspace. The safe and efficient integration of UAS, particularly small UA, into existing controlled and uncontrolled airspace presents a variety of issues and novel challenges. Recent studies forecast significant growth of UAS operations, leading to a shift of focus to operations in the low-level environment and above populated areas, with various types of operations and UA. This will likely include:

- operations at altitudes in the very low-level structure (e.g. below 150 metres or 500 feet above ground level (AGL));
- systems with high levels of automation and connectivity;
- greater number of operations, which raises questions about the sustainability and scalability of a UTM system and the ability of ATM infrastructure to accommodate these new users;
- flights not conducted in accordance with IFR or visual flight rules (VFR) with the potential of establishing UAS specific flight rules; and
- reliance on data links (either non-traditional ground-based links, in-air C2 Links or data links with UTM systems), raising new challenges related to frequency spectrum, resilience and cybersecurity.

### Gaps

Many of the gaps addressed below become more significant at the boundaries between UTM and ATM systems and/or when UA transition between these systems.

- *Airspace classification*. The current airspace classification scheme as developed for manned aviation may not effectively support visual line-of-sight (VLOS) or BVLOS operations. This gap includes the potential modification of current classes of airspace or potentially creating new classes of airspace to accommodate the range of needs brought by UAS operations.
- *Airspace access*. The policies, rules and priorities required to support equitable access to airspace must be developed (the European Union, for example, is examining policies on fair access to airspace).
- *Rules of the Air.* Rules of the Air which specify flight rules, right-of-way, altitude above people and obstructions, distance from obstacles and types of flight rules, all of which, as written, are incompatible with the intended operations within UTM systems must be addressed.
- *Operational procedures*. Procedures specific to the UTM system, including normal, contingency and emergency scenarios, are needed. Such procedures would need to be harmonized with ATM systems whenever UAS operations are planned near the boundary between UTM and ATM or if UA will transit from one system to the other.
- *Liability*. Liability and insurance implications for USPs in relation to UAS operators must be determined.
- *Certificatio*n. Certification of the UTM system, particularly when interacting with an ATM system, and, for UA, meeting the principles of airworthiness, scaled to an appropriate level based on risk(s).

- *Data standards*. Appropriate standards for data required to support UTM safety-related services, including security and cybersecurity, are needed.

- *Data exchange*. Exchange of data between UTM and ATM systems as well as between multiple UTM systems will require common or compatible data formats and protocols. These are usually defined by standardization bodies. Determining the extent to which existing standards can be used and new ones need to be developed remains a work in progress.

- *Positional references*. Common altitude, navigation and temporal references for manned and unmanned operations are needed. There are gaps in the use of reference points and equipment providing different levels of accuracy and performance in the measurement of altitude, navigation or time.

- *Interface between UTM and ATM*. There is a need to develop procedures and adequate tools to ensure the sharing of information and the interoperability of the two systems, and to identify roles, responsibilities and limitations.

- *Data recording*. Data-recording policies and capabilities, similar to ATC data retention, are needed to support incident/accident investigative requirements.

- *Communications*. Remote pilot interfaces and capabilities for communications with the UTM system must be developed. These include the ability to interface/communicate with ATC and pilots of manned aircraft.

- *Alerting systems*. The safety and integrity of the UTM system, failure-alerting and failure management must be addressed. Policies, guidance and procedures will need to be developed to address the degradation or failure of the various UTM components or entire UTM system.

- *Contingency management protocols*. A dynamic operating environment must have operating protocols that account for contingencies both of the UTM system(s) providing multiple services and of the aircraft operating within the UTM system.

**Issues**

The issue of modification, adaptation or applicability of requirements for airspace and procedure design when considering topics such as navigation performance has yet to be addressed.

To ensure system reliability and safety, frequency spectrum availability and supportability need to be determined based on the UTM system architecture.

The establishment of a UTM service within a volume of airspace may affect the classification of that airspace (e.g. changes from Class G to D airspace).

The UTM and ATM interface, including responsibilities and procedural development, must be addressed to ensure compatibility between manned and unmanned operations.

UTM and ATM systems may have different communications, navigation and surveillance (CNS) requirements for different aircraft. The systems need to exchange data effectively so that each system can manage the aircraft relevant to its responsibilities. CNS requirements in UTM may differ from ATM.

Data sharing protocols will need to consider State data privacy policies.

Further research is required to support the development of the interoperable standards and protocols for the elements of UTM and ATM data exchange.

**Challenges**

Aircraft participating in the UTM system must be separated from each other and from other hazards (e.g. buildings, terrain or adverse weather). This separation management should include guidance and responsibilities complemented by other tools and procedures to properly address scalability. Separation management may have to be supported by additional standards, policies, capabilities or tools, including:

- a DAA capability to identify/detect and avoid conflicting aircraft and any other hazards;
- methodologies to allow improved or enhanced detectability and conspicuity of UA by manned aviation;
- assignment of responsibility for conflict management and separation provision, particularly in low-level airspace, which may include unique solutions such as separation provision being delegated to the UA or the UTM system;
- development of UA separation standards within the UTM system, which may include the need for safety margins based on elements such as airspeed, weight and UA equipment;
- assessment of existing and future separation standards between UA and manned aircraft whenever they operate in proximity to each other;
- determination of the relevant surveillance capability for the UTM system to support the integration of new or novel aircraft and operations;
- development of policies to address means of compliance or system approval for UTM systems;
- implementation and maintenance of a safety management system as currently required by aviation systems related to manned aviation; and
- achievement of a required data quality (e.g. on availability, reliability, accuracy, integrity and continuity) of the system. The standards applied to UTM systems that are intended to interface with the ATM system will need to be compatible and interoperable.

# Summary of Conclusions

As discussed previously in this document, UTM as a concept or capability, is still under development. ICAO is continuing its tasks as a global aviation forum to support States, UAS industry leaders and academic and aviation professionals, and is exploring current, state-of-the-art solutions for UTM and using that information to develop the UTM framework and core principles.

This framework is not intended to endorse or propose any specific UTM system design or technical solutions to address the UTM challenge; instead, its aim is to provide an overarching framework for such a system. The intent is for this to be a living document: as new or additional information is gained, the UTM framework will be updated.

The developmental nature of UTM makes it difficult to predict how a follow-on framework will be organized, validated and certified. More participation from industry or future business advocates will be necessary to explore the minimal set of safety issues in product deployment and development, which will potentially lead to global interoperability.

Edition 2 of this framework document contains six appendices synthesizing information gathered from the submissions to ICAO’s 2017 and 2018 Requests for Information (RFI) and material provided during ICAO’s first two DRONE ENABLE Symposia.

# KEY TECHNICAL AREAS

# APPENDIX A

# REGISTRATION, IDENTIFICATION AND TRACKING

**Presentation review (from DRONE ENABLE 1)**

Registration, identification and tracking are separate features that provide specific capabilities for different purposes.

Registration makes it possible to identify an individual aircraft and the State in which it is registered. The registration consists of a unique alphanumeric system affixed to the aircraft. Ownership details can be obtained through the State that has registered the aircraft.

Individual aircraft can also be identified from one or more other unique signatures, for example encoded information transmitted via radio or digitally. Hence, identification is a feature that can be made possible via registration (usually visually) and by a wide range of other techniques, many of which may involve technology that facilitates identification from a distance.

Tracking consists of locating and tracing individual aircraft through airspace over a period of time. To do so, specific, unique information is needed to identify the particular aircraft, and techniques are required to determine its location. These location features can be independent of the aircraft (e.g. surveillance systems).

In the context of UAS and UTM, it is necessary, at a minimum, to be able to identify and track each aircraft in order to ensure safety and the efficient management of the airspace. Registration details provide the CAA of the State in which the operation is occurring to identify the nationality of the aircraft, the operator and what person or machine is controlling the aircraft. Registration may also assist non-aviation-related agencies concerned with issues such as security, law enforcement and privacy.

It will therefore be necessary to determine and harmonize common national, regional or international approaches that will define and assign suitable unique registration identities for all UA that will potentially operate in the UTM system. These registration identities will have to be structured and formatted to address visual markings wherever practical and the technical solutions supporting the UTM system as it evolves. It is envisaged that, in a cooperative communications-based UTM framework, greater use of electronically defined and transmitted identification techniques will be necessary along with a range of tools to decode and share this information, whilst respecting the need for security and protection of personal data.

During ICAO's first DRONE ENABLE Symposium, organizations shared several focused views with specific attention on their product offerings. Most organizations focused on methods of sharing identification data using available technology and standards or proprietary systems to facilitate use, acceptability and enforcement. Secondary elements included the use of current security and cybersecurity aspects, but did not address safety implications related to system failures or security breaches.

Overall, ICAO received limited information on solutions for addressing systemic topics and on how to do so in an open and interoperable manner.

ICAO used the knowledge and input from presentations and RFI submissions to gather the information provided below.

**Registration**

Registration proposals varied from the simple identification of only the aircraft and pilot/operator to systems registering everything about the aircraft, UA control station, operator, pilot, certificates and any pre-approved flight authorizations. The overarching needs driving such proposals were the need for accountability and enforcement, which have a direct impact on safety and security. Given the anonymous nature of UAS operations (nobody on board and an operator that is not clearly visible), this issue has become critical and may warrant an international minimum standard similar to that for manned aviation. States may determine who has local access to the registration information and how that information is safeguarded. This registration system may be an integral part of the UTM system or simply a plug-in module with the CAA in charge of the registration system.

**Identification (ID) and electronic identification (E-ID)**

Similar to the registration proposals, proposals on ID and E-ID solutions varied considerably, particularly with regards to the information needed. A common element identified was the requirement for the transmission of the UA ID and UA control station location to enable the rapid identification of a specific UAS. This was primarily for the direct functioning of the UTM system and, additionally, for safety, security and accountability with regards to the integration of UAS within the existing aviation community. Without this capability, it would be difficult to garner public acceptance of routine UAS operations. Again, it was recommended that a minimum international standard should be introduced, with States developing local variations. In addition, many technical and procedural issues that would need to be addressed at both the international and State levels, depending on the system architecture, were identified. These included, inter alia:

- cybersecurity;
- communications and frequency spectrum availability;
- cost and financing;
- compatibility versus interoperability;
- real-time use and updates; and
- required performance standards.

**Tracking**

Regarding proposals on tracking, it was evident from presentations and submissions that in order for a UTM system to function at a basic level, it must be able to track all UA, participating or not, using a minimum of 4D geospatial data. This was also required for safety, security and accountability within the UTM and manned aviation systems. The secondary need addressed the collection of data to aid in airspace design and management. The ability to track UA within the UTM system was considered a critical service that had implications on system reliability, resilience and redundancy at the manufacturing and operational levels. Other considerations such as system accuracy, real-time information, delay-refresh rates, flight data records and storage of and access to data would need to be resolved in order for a UTM system to function effectively. The last issue identified was related to “ghost operations”, which would involve UA that would have to be managed by the UTM system while masking the identification and position (e.g. for police operations).

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# KEY TECHNICAL AREAS

# APPENDIX B

# COMMUNICATIONS SYSTEMS

**Presentation review (from DRONE ENABLE 1)**

The integration of UAS operations into controlled and uncontrolled airspace presents a variety of issues and novel challenges for information systems.

The primary means of information dissemination and coordination between entities providing UTM services may be a distributed network of highly automated systems via API.

The same architecture may also support multiple service providers, if the operational volume and complexity require. A common protocol must be established to ensure that information systems are safe, secure, reliable and interoperable, and adhere to a performance-based regulatory framework.

UTM system information protocols and interfaces will play a key role in ensuring that the system enables the safe integration of UAS into shared airspace. The development of minimum performance and interoperability standards for communications protocols should be taken into consideration, including, as applicable, those for:

- C2 Link between UA control stations and UA;
- aircraft-to-aircraft communications between UA;
- communications link between UA and other airspace users (e.g. manned aircraft), as necessary; and
- communications between remote pilots and the respective UTM and ATM systems.

***Communications solutions***

Given the rapid advancement of technology, there will be a variety of possible technological solutions that may support a framework for communications systems. As work progresses, different concepts of UAS communications service provision through entities such as ANSPs, governmental organizations and private third-party suppliers will evolve, similar to those being utilized for ATM systems. Such entities may play a key role in centralizing all communications between UAS and stakeholders (ATC, law enforcement, etc.) and in assisting with strategic deconfliction, situational awareness, flight planning and authorization of UAS operations in the respective airspaces and collaboration between UAS operators and flight information management systems (FIMS).

With the introduction of UTM in the future, it is envisaged that a key emphasis will be placed on aircraft-to-aircraft operations. Direct aircraft-to-aircraft communications enable UAS operators or remote pilots to communicate their flight plan and other relevant information with each other. Various technologies that have been developed for the automobile industry, including dedicated short-range communications (DSRC)[1], are being considered to support such aircraft-to-aircraft operations.

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[1] DSRC is a two-way, short-to-medium-range wireless communications capability that enables very high data transmission for vehicle-to-vehicle and vehicle-to-infrastructure automobile communications under the Intelligent Transportation Systems (ITS) programme of the United States Department of Transportation.

***Frequency Spectrum requirements***

The International Telecommunication Union (ITU) plays a decisive role in allocating protected frequency spectrum to UAS operations, which may be necessary for safety-critical functions. If the communications link between remote pilots and aircraft is lost or compromised, serious safety-related consequences may arise. For example, a C2 Link between UA and UA control stations is required for the safe operation of UA under VLOS and BVLOS conditions.

A number of frequency bands in the fixed satellite service (FSS) are being considered for the provision of the C2 Link for UAS, albeit with specific conditions pertaining to the governance and usage of those bands imposed by the ITU and ICAO. This might be an option to consider for some UTM operations.

Standards for communications systems will need to cover the relevant safety implications owing to lost C2 Link events, as well as metrics pertaining to the latency, integrity, availability and redundancy of data transmission.

The anticipated operational needs for frequency spectrum usage revolve around four main elements:

- aircraft-to-aircraft communications between UA;
- communications between UA or UAS operators, remote pilots and the respective UTM or ATM systems;
- communications for the C2 Link; and
- communications for the application of DAA.

In this regard, frequency spectrum sharing will be especially vital for urban areas, where operations will be significantly more congested than in rural or remote areas. The frequency spectrum capacity currently required for remotely piloted aircraft systems (RPAS), as defined by ITU designations at the World Radiocommunication Conference 2012 (WRC-12), are:

- 34 MHz for terrestrial systems; and
- 56 MHz for satellite systems.

Concerns regarding frequency availability and suitability, as well as challenges relating to the protection of airspace and space-ground frequencies will need to be addressed and closely coordinated with the ITU.

***Cybersecurity***

There are significant cybersecurity risks and vulnerabilities that must be taken into consideration. A robust security framework must be established to address potentially malicious attacks to communications systems, including C2 Link disruptions, Global Navigation Satellite System (GNSS) jamming or spoofing attacks, and the manipulation of information exchanged between UAS and between UAS and UTM systems, which may result in erroneous advisories, unwanted changes in flight paths and increased risk of collision.

**Additional considerations**

The presentations and submissions made at the first DRONE ENABLE Symposium provided some indications of the type of communications technology that might support a UTM system as well as some questions that would need to be answered before deciding on the way forward. Subject to validating that the required performance and security requirements can be met, technologies such as Long-Term Evolution (LTE), 3rd Generation Partnership Project (3GPP) technologies or a combination of terrestrial and satellite-based communications were mentioned. For any of these technologies to be selected, issues regarding suitability for urban or rural areas, sufficient availability of bandwidth or capacity, frequency spectrum availability or resilience to interference will need to be addressed.

# KEY TECHNICAL AREAS

# APPENDIX C

# GEOFENCING-LIKE SYSTEMS

**Presentation review (from DRONE ENABLE 1)**

States may wish to restrict the operation of UA in certain areas due to various reasons. These reasons include, but are not limited to: sensitive or safety-critical infrastructure, military activity, accident and law enforcement activities, public and social gatherings, aircraft landing areas and VIP protection.

When such restrictions are imposed by State or local governments, information on the areas may be published by States or ANSPs in Aeronautical Information Publications (AIPs), dedicated websites or various mobile applications, or may be activated by NOTAM. The data related to these areas must be valid, accurate and issued by a competent or approved agency that is clearly identified. These data may be of a different nature than existing aeronautical information but will have to be harmonized with applicable aeronautical information standards. Additionally, aspects such as the shape of the specific areas may require standardization due to the impacts on the embedded system's performance.

A geofencing function or service includes an airborne piece of equipment (hardware or software, or both) that can currently be found on some small UA; however, no associated performance requirements or standards exist for the development or approval of such systems at all times.

It is envisioned that a geofencing/geoawareness-like system will either prevent UA from entering airspace in which they are not permitted to operate or, alternatively, may be used to prevent UA from leaving specific areas. The system would likely have to be associated with an approved service that provides accurate information on airspace availability and restrictions. This will lead to benefits in terms of safety and security and reduce requirements concerning the competencies of UAS operators. However, consideration must also be given to the potential unintended consequences should UA be prevented from entering airspace when doing so is required to prevent a mid-air collision or for another reason related to the safety of the flight.

Draft UTM concepts include two components of geofencing functions or services:

- static: when the data provided to support the geofencing/geoawareness function or service relies on published, stable data (e.g. AIP, list of restricted airspace); and

- dynamic: when the restricted areas are temporary and may be established with little or no notice (e.g. emergency scene, public event). There should be the capability to permit accredited authorities to create temporary restricted areas on short notice, for example, to protect an area of public safety concern. In such situations, a system for transmitting these restrictions to UA already in flight will be needed.

As currently exists for manned aviation, a common set of standards and processes for airspace restrictions should be developed to address the integration of temporary restrictions, approval of accredited authorities, common requirements for who can establish or validate restricted areas, and the conditions under which these areas may be established. Processes or policies should also be established to avoid having too many restricted areas that may create congestion or safety issues for manned aircraft or UA in flight.

A geofencing capability is envisaged as a service providing the data (static and dynamic) and information on the UA position that are required to alert the remote pilot of when the UA is approaching or crossing a geofenced area, to enable the UA to avoid prohibited areas or to deny access to such areas. A geofencing/geoawareness system could include different layers or buffer zones around the geofenced area that would trigger different types of alerts (e.g. inner, intermediate and outer).

Some considerations on geofencing/geoawareness functions or services include:

- Data integrity. AIS and GIS data and information must be valid, current and supplied by a recognized or accredited source.

- Accuracy of the UA position. Positional information must be accurate enough to ensure that the UA does not enter the geofenced area (can be coupled with the use of buffer zones). Current GNSS positioning technology may not provide a sufficient level of accuracy, reliability or redundancy, particularly in areas with limited reception, such as urban canyons. The UAS operator or remote pilot may be required to validate the UA position accuracy prior to flight operations.

- Assessment of whether the UA is about to enter, or has entered, a geofenced area, and alerting the remote pilot and/or UA, which may be able to react automatically.

Geofencing may have to be removed for some operations in some areas (e.g. UA authorized to operate at airports, UA performing inspections at power plants or UA used by public safety agencies). A geofencing function or service provided in UTM may deal with a certain number of these exceptions in an automated way, facilitating the authorization process for specific UAS operators.

Other considerations regarding geofencing that were raised at the first DRONE ENABLE Symposium include:

- Contingencies: how to mitigate fly-aways, lost C2 Link, UA emergency recoveries, etc.

- Geofencing should not replace the need for sufficient knowledge on the part of the remote pilot of airspace structure, airspace constraints and regulations.

- Methods to address or enforce intentional non-compliance with geofencing must be developed.

- Prior to deciding if geofencing/geoawareness should be compulsory for a UTM system, other factors should be assessed:

    a. the availability of alternative methods for ensuring that UA do not violate airspace boundaries, such as: active monitoring of UA flight trajectories, accurate performance of navigation equipment and properly trained remote pilots;
    b. the establishment of performance requirements for UA operating within the UTM system to address issues such as navigation, position and use of common altitude references; and
    c. the availability and quality of airspace data within UTM systems, particularly across States.

- it was recognized that geofencing could mitigate risks arising from the lack of situational awareness and airspace appreciation often found among recreational users of these aircraft and could be a separate requirement outside of the UTM system.

Even if geofencing/geoawareness may not be considered a mandatory requirement for a UTM system, it may provide some mitigation measures and may be used by UAS operators and remote pilots operating in areas where they are not familiar with the airspace (e.g. a foreign country). During the first DRONE ENABLE Symposium, it was indicated that international standards would likely be needed to address the following issues:

- Processes and procedures must be established to provide special authorizations for approved UAS operators (or UA) to override geofencing restrictions and enter specific geofenced areas.

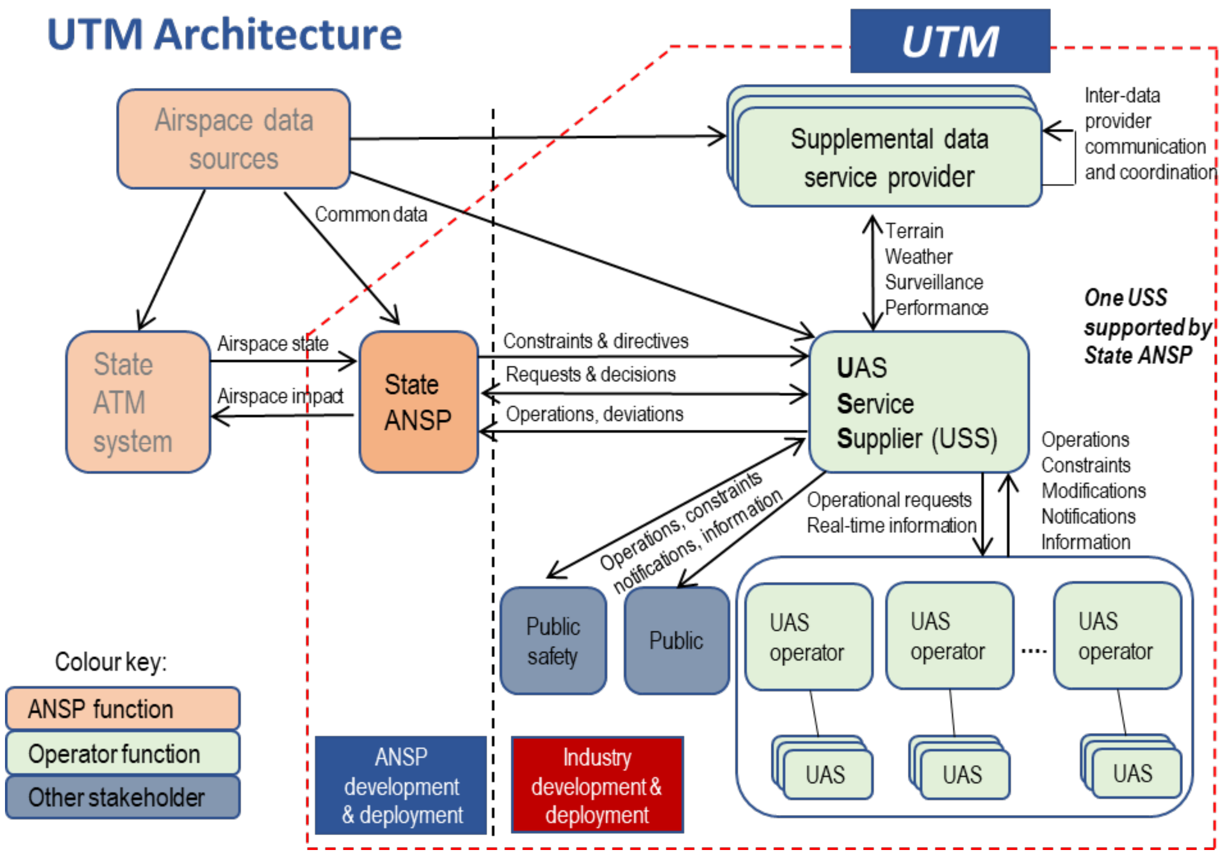
- Anticipated behaviours of a UA when approaching a geofenced area (land, hover, wait for remote pilot instructions, return to home, circumnavigate, etc.) must be identified and system responses developed.

- UA actions under contingency operations (lost C2 Link, fly-aways, emergencies, etc.) and system responses must be developed.

# APPENDIX D

# POTENTIAL UTM ARCHITECTURES

The following are two examples of a potential UTM architecture. It should be noted, however, that the UTM architecture is not fixed and may differ from what is shown below.




Software Developer
Surveillance and other Service Providers
Other Supporting Organizations
State UTM Operator/Service Provider
Communication Service Providers
Navigation Service Providers
Infrastructure Service Providers
Risk Assessment Organization
UAS operators
Insurance Underwriters
Security Service provider
Training Organization
National Security Agency
Military Power
State Server
Public Security Agency
ANSP
Pilot Competency Information
Indusry Regulation Body
Meteorological Information
Basic and classified GIS
Aircraft Registration Information
Aeronautical Information
State Security Information
Public Security Information
Agricultural, Forestry and Sports Regulations Bodies

# KEY TECHNICAL AREA

# APPENDIX E

# UTM-ATM BOUNDARIES AND TRANSITION

**Presentation Review (from DRONE ENABLE 2)**

Several DRONE ENABLE 2 presenters expressed views on the topic of UTM-ATM boundaries, with specific attention on the currently available product suites for ATM and potential UTM technology solutions. Most of the solutions have been focused on the products and methods of sharing data using the available technology/standards and provision of services to UAS, many of which are under development by various national and international standardization bodies. Additional discussions considered the use of airspace, but they did not address safety implications related to non-defined boundaries and responsibilities between UTM and ATM.

Airspace, which is currently used by civil aviation for their operations, is managed, with different levels of services, by the established ANSPs. ANSPs are following air traffic management rules set by ICAO (Annex 11 — Air Traffic Services, Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444 and others) and regional/national regulations. Flight information service (FIS) is provided either by a flight information center or by an air traffic control unit (according to ICAO PANS-ATM) and includes information which is intended to enhance safety.

Aviation, including ATM, has a long history during which a high level of safety has been developed and is maintained. A notable characteristic of ATM is that it functions with a well-established and proven safety management system, however its procedures and structures may not allow for quick developments and implementations. By contrast, UTM is innovative and fast, but its level of safety and robustness has not been defined and validated. Accordingly, a high degree of complexity emerges from efforts to integrate these two systems.

The establishment of boundaries has not only operational and technical elements, but also legal elements. As UTM is implemented, the fact that the airspace will be shared between manned aircraft and UA creates a need to identify and confirm the roles of UTM and ATM related to airspace and traffic management responsibilities and functions. Several DRONE ENABLE 2 presenters noted that interoperability is a key requirement for UTM-ATM interface.

Several DRONE ENABLE 2 presenters also outlined the complex gap between responsibilities of UTM and ATM. The gap has materialized from the fact that the process for designation of UTM service suppliers, their certification, and how they should demonstrate a minimum level of safety and quality of service has not been defined. On the other hand, established ANSPs are regulated and follow well established procedures.

Besides the gaps which are complicating the establishment of UTM-ATM boundaries, it is hard to achieve the development of UTM in isolation from the existing ATM system and its services.

Some of the UTM services presented during DRONE ENABLE 2 have similarities with ATM services; therefore coordination with ATM is vital. Other UTM services are complementary to ATM as services are expanded to airspace users in volumes of airspace where ANSPs currently provide limited or no services (e.g. FIS). Although it is likely that these services will need to interact, there must be no overlap of conflicting or incompatible services or areas of responsibility. As a consequence, presenters expressed the view that UTM services may, in fact, be shared between UTM and ATM.

Several presentations were offered at DRONE ENABLE 2, addressing UA capabilities for operating in all types of airspace and at all altitudes/levels. Discussion topics included scenarios where manned aircraft and UA will be required to cross the boundary between UTM and ATM, whereas in other situations they will only operate in close proximity to that boundary. In both scenarios, an aircraft being managed by one system (UTM or ATM) may be at increased risk of becoming a hazard to aircraft being managed by the other system.

**Introduction**

This Appendix addresses practical issues and future implementation considerations of a UTM operational architecture in airspace where existing ATM services and protocols are generally provided for many, if not most, volumes of airspace within a State's jurisdiction. Notwithstanding the same objectives of UTM and ATM (i.e., to prevent collisions and enable safe and efficient operations in the airspace) there are significant differences between the means by which UTM and ATM may achieve this end. It is, accordingly, important to provide States with material that speaks to the unique circumstance of airspace in which aircraft under either UTM or ATM may be operating in or transitioning between UTM and ATM.

In accordance with PANS-ATM, the ATM system provides air traffic management through the collaborative integration of humans, information, technology, facilities, and services, supported by air, ground, and/or space-based CNS. The same definition should also apply to UTM. It is, however, important to recognize the difference between the two systems from an operational perspective.

For the purpose of the ICAO UTM Framework, the use of the term "boundary" with regard to UTM and ATM is intended to address the applicable delineation between UTM and ATM systems. To this end, the UTM-ATM boundary should be understood as any physical boundary, or a combination of boundaries, as set by airspace design, a service boundary defined by distinct sets of services provided by an ANSP and USP, and/or a system boundary defined by the technical CNS/ATM system.

Accordingly, at the outset, the exercise of addressing UTM-ATM boundaries focuses primarily on UTM itself as notionally defined by airspace. Many concepts of UTM services are currently projected to support low-altitude operations where there is limited need for active traffic control. As additional automated capabilities are added to future developments of aircraft, however, it is possible that UTM and ATM services (and even systems) will not be as neatly identified by particular classes of airspace, or even types of aircraft operations.

In the near-term, airspace segregation is likely to be the most commonly deployed solution. However, as operations develop, it seems appropriate for the States to identify where the course of operational, airspace, and technology elements might require additional planning (e.g., appropriate rules, policies, and procedures) for the integration of aircraft operating under different traffic management systems, albeit in the same airspace. This Appendix therefore draws on assumptions about the nature of operations that may be more likely conducted in the medium-term, rather than the near-term.

**The Issue of Boundaries**

At the outset, it was recognized that safety is paramount to the use of airspace, regardless of the class of airspace or operation being conducted. Transitioning between UTM and ATM should not compromise safety of operations. As integration increases, operations will overlap but these operations should not diminish the level of safety. It is anticipated that this key aspect of operations will be further developed at DRONE ENABLE 3.

Responsibilities for flow management, separation and collision avoidance should be considered by States in developing procedures and rules for UTM-ATM boundaries. Although the activities may be different in the two systems, the responsibility to ensure safety remains with the relevant service provider, as regulated by the State. There are established ATM processes for assigning or delegating airspace service provision; for UTM the same processes should be used. The safe separation of aircraft is a set responsibility to be fulfilled by the ATM service provider. However, given that UTM will not provide the same separation service as ATM, the established criteria may not be appropriate for these operations and may require a different set of standards for UTM operations. UTM and ATM users are thus responsible for awareness of the level of services provided.

Interoperability is also an essential requirement. There will be a need to share operational information between both ATM and UTM providers. ATM and UTM information must be accessible to relevant stake holders (airspace users, service providers, states, etc.). Architecture may permit coincident (overlapped) ATM and UTM operations, but at a minimum, the exchange of essential information at the boundary must be ensured for safe and efficient operations.

ICAO Annex 11 - *Air Traffic Services*, Chapter 3, paragraphs 3.5.and 3.6 detail the requirements applicable to *Responsibility for Control* and *Transfer of Responsibility for Control*. These same principles are equally applicable to the transfer of responsibility between USPs and to transfers between USPs and ATS units. In the case of the ATS unit, this may not involve control of the UA, however, the information applicable to the flight of the UA will need to be exchanged for purposes such as the issuance of traffic advisories,

(*See* Appendix F, Essential Information Exchange between UTM and ATM Systems for more information on information exchange suggestions.

A phased approach is suggested in order to integrate unmanned and manned aircraft, when flight paths are adjacent to, or within, the same volume of airspace. The guidance in this Appendix is irrespective of the performance capabilities of aircraft that seek to access any volume of airspace, including at UTM-ATM boundaries. The subsequent paragraphs describe questions and considerations to be addressed when integrating operations between UTM and ATM.

*Key Considerations in Establishing Operations at Boundaries.*

The Determination of Boundaries

- UTM operations may require new ways of managing airspace categories and volumes, based on future concepts, which may affect the criteria followed in designing the interactions between UTM and ATM.
- Performance capabilities of UA and their operators (e.g., aircraft characteristics of speed, size and maneuverability) should be considered when designing the size and shape of UTM - ATM boundaries.
- The airspace design should be relative to the type and performance characteristics of the UA and other aircraft operating in or adjacent to the volume of airspace.

Phased Integration of Boundaries

- Limitations in how airspace is managed between UTM and ATM drive the need to address how the two management approaches can be integrated.
- As additional concepts are tested and made available, these differences in management approaches will begin to diminish. To reach integration between UTM and ATM testing will likely need to be implemented in a phased approach.
- In order for the crossing of boundaries between the UTM and ATM systems to become seamless, airspace users and ATM/UTM personnel will need to understand the operational requirements of both systems.

**Common Elements of Operations at the Boundary**

UTM-ATM boundaries require considerations of operational, airspace and technical elements at a minimum. These elements should address issues pertaining to transition between UTM and ATM or adjacent operations.

*Operational considerations*

It is understood that the current flight rules (VFR, IFR) are insufficient to accommodate UAS operations. Any changes to the flight rules will need to be consistent and complementary to the ones defined for manned aviation. States will need to decide how to apply the flight rules at the boundaries between UTM and ATM.

It is also expected that a reference system for the vertical position of aircraft, common to UTM and ATM systems, will be necessary to accurately and consistently provide appropriate vertical separation.

States should consider several key operational aspects, while establishing boundaries between UTM-ATM areas of responsibilities. These include, inter alia:

- Identification of roles and responsibilities of UTM and ATM systems in terms of level of service provided and service responsibility should the two overlap.
- Development of operational procedures and coordination processes:
  - for transitioning between UTM and ATM;
  - to allow traffic under UTM control to operate in an ATM environment and vice-versa; and
  - for operations in close proximity to adjacent airspaces
- Establishing separation standards between UA and between manned aircraft and UA.
- Establishing the prioritization of operations (e.g. in-flight emergency or medical operations having priority over other aircraft).

*Airspace considerations*

The current airspace classification scheme and the requirements associated with specific airspaces, may not accommodate UAS operation as envisioned under UTM given the highly automated nature of UTM operations. Analysis of such gaps will be needed to determine if changes to the airspace classification scheme will be required. Such changes could address user responsibilities, types and levels of services to be expected, equipage requirements for airspace access, and airspace authorization requirements.

Any such airspace changes would require the completion of an SMS assessment to ensure levels of safety are maintained.

*Technology considerations*

States should consider several technological aspects, while establishing boundaries between UTM and ATM areas of responsibilities. These include, inter alia:

- technology to support collision avoidance;
- automation to support traffic management and transitions between UTM to ATM;
- information exchange capabilities between UTM and ATM systems for operations planning purposes and to enable situational awareness; and
- capabilities to meet performance requirements needed to achieve interoperability (e.g. CNS requirements).

## Key Technical Areas

# Appendix F

# Essential Information Exchange between UTM and ATM systems

**Presentation Review (from DRONE ENABLE 2)**

Conference attendees provided information on content of essential information that might have to be exchanged between UTM and ATM systems, as well as the challenges encountered during the information exchange process.

UTM may involve new types of information that is not included in current ATM information. The relevance of this new information to the ATM system will have to be examined to determine if such information needs to be exchagned.

**Introduction**

This appendix aims to provide guidance to States, regulators and industry on specific elements that need to be considered for the exchange of essential information. These considerations are irrespective of the direction of the flow of information. Due to the uncertainty of how airspace will be organized and what the actual system requirements will be, the list of elements can neither be exhaustive nor will it be suitable for all possible scenarios.

It is currently assumed that each airspace user will be managed by only one entity at a time, either the UTM or ATM system. However, an airspace user may receive information from several UTM or ATM sources.

Currently, the ATM system is a 'human centric' system whereas UTM is envisioned as digitally based. The information exchange requirements between these two systems will therefore have a significant impact on human factors, the consequences of which will require extensive consideration.

**UTM/ATM Interoperability Considerations**

System wide information management (SWIM) principles should be applied to support information exchanges between UTM and ATM. For this to occur:

- UTM solutions should leverage and remain consistent with the work of ICAO regard to services, information, technical infrastructure and IP-based connectivity, when appropriate; and

- current aviation connections, through SWIM, will need to be extended to new airspace users, who will also need to use information services and data exchange models.

Current references such as the ICAO ATM Information Reference Model (AIRM) and global information exchange models such as the Aeronautical Information Exchange Model (AIXM), the Flight Information Exchange Model (FIXM) or ICAO's Weather Information Exchange Model (IWXXM) should constitute the primary baseline for UTM-ATM information exchanges.

There are a number of requirements and associated risks for data sharing. These include, inter alia, cybersecurity, data exchange protocols, accuracy, data storage, system interoperability and system performance. To address these issues, States, ANSPs and USPs should also define the quality requirements for the services supporting UTM-ATM information exchanges and for the data that will be exchanged by these systems. Additionally appropriate service management systems should be established. It will also be important for the system interface to include a process for identifying and verifying the source of the data. The ICAO *Manual on System-Wide Information Management (SWIM)* Concept (Doc 10039), may be beneficial when addressing SWIM related issues.

**Elements of Information Exchange**

1. Service Provider considerations

- Airspace

Airspace is usually defined and classified by States, with boundaries relating to coordinates and vertical levels; it can either be permanent or temporary. The exchange of aeronautical information provides information on defined airspace dimensions either in advance or real-time, as the need allows. An agreement between serivce providers may be needed to exchange information on changes in airspace structure, either by using the established aeronautical information regulation and control (AIRAC) cycle including NOTAMs or perhaps an alternative means of providing real-time updates.

Future information exchange such as dynamic geo-fencing may necessitate a more direct exchange of airspace information between UTM and ATM systems.

Aeronautical data will need to be enriched with any new airspace structures, and UA-specific information such as: geofencing, UA navaids, UA corridors or airways, UAS procedures, UA airports and landing areas, etc.

When airspace data is exchanged and used, the format and scale used will need to be defined for the exchange that is fit for purpose taking into consideration system and user needs. All data should meet a minimum level of accuracy, be delivered in the time frames required, and be validated/certified.

The entity responsible to create airspace definitions should be clearly identified.

The system requirements for authenticating the information source will need to be established.

- Strategic coordination between UTM and ATM:

  Information associated with capacity management, similar to air traffic flow management procedures for manned aviation, should be developed and communicated between systems for the safe and efficient flow of all air traffic. Such information may need to be coordinated with operators (e.g. to alleviate the effects of limited energy (fuel) levels of certain UA and negative impacts on the overall traffic flow).

  Strategic coordination agreements between UTM and ATM may be required, similar to letters of agreement between air traffic control units today. This may help in facilitating standardized processes to approve/clear aircraft between the two systems. These processes and data would also enable strategic de-confliction of aircraft between UTM and ATM.

- Tactical coordination and de-confliction:

  Although there was no discussion within the RFI papers on this topic, this is an area that requires further analysis and consideration.

  When required, the provisions for de-confliction or separation requirements for aircraft can be included in the data exchange. Systems would need to exchange information to support any required separation standards,once developed.

  Real-time management of emergency and contingency situations may require tactical data exchange.

2. Considerations for information exchange between systems

This section introduces some UTM and ATM information exchange considerations that States may need to address when approving a UTM system to interact with an ATM system.

- ability to verify and authenticate the identity of the entities exchanging information;

- confirmation of the integrity of the information being exchanged;

- conformity of system connectivity to agreed system requirements, including the quality of the services supporting the UTM-ATM information exchanges, to include: availability, confidentiality, integrity, latency, recoverability and reliability; and

- monitoring of the technical infrastructure for health, faults and performance degradations, to ensure information exchanges according to agreed requirements.

3. Aircraft User Information Elements

As UTM concepts mature, the set of information exchanged between UTM and ATM systems will become better defined. The information listed here provides an example of the type of information that may be exchanged. The type of information will determine if it supports strategic coordination, tactical coordination or both.

There are different levels of information, including some that might be relevant to the immediate operation, some for management of the systems, and some that address other requirements. The types of data that may need to be exchanged include, inter alia:

- aircraft identification and registration information (some of this information may be regulated by the State)
  i. E-identification
  ii. Ownership information
  iii. Operator contact information
  iv. Pilot contact information
  v. State of Registry and State of Operator
  vi. Aircraft type
  vii. Aircraft category (e.g. aircraft, rotorcraft, glider, vertical take-off and landing (VTOL), hang-glider).
  viii. Wake turbulence considerations
  ix. Aircraft surveillance capability (e.g. ADS-B, Mode A/C or S)

- UA method of control (e.g. RPAS, automated, or other);

- irrespective of the method of control (RPAS, automated, or other), does the aircraft carry people;

- UA position – 4D geospatial information to required standard;

- source of position data for both lateral and vertical position information (e.g. certified/non-certified, validation, reliability, accuracy, barometric altitude/GNSS altitude);

- flight plan, including flight notification;

- flight plan conformance information;

- current flight trajectory (i.e. the immediate intent of the UA rather than its flight plan route);

- flight rules the UA is operating under;

- airspace access and authorizations;

- UA performance capabilities (e.g. minimum or maximum speed, climb rates, max. altitude);

- UA system performance (e.g. the UTM established required communication performance (RCP), required surveillance performance (RSP), required navigating performance (RNP) to which the UA must comply);

- ACAS or DAA capability - requirements have yet to be determined depending on separation standards;

- emergency or contingency status - information about existing emergency/contingency status either initiated by the aircraft or by the system/ATC;

- contingency procedures - this could include a proposed flight path, procedures during lost C2 Link or contingency landing sites;

- fly away / lost C2 Link routings;

- emergency considerations - including data relevant to search and rescue (e.g. maximum endurance, humans on board, dangerous goods on board);

- C2 Link type - how is the UA linked to the remote pilot station;

- C2 Link status - quality and status of C2 Link (e.g. lost C2 link, partial loss);
- ATC communication link type (e.g. VHF, telephone, data link);
- ATC communication link status;
- priority status (e.g. aircraft in distress, medical);
- information to facilitate charging of service fees - this may originate through the ID and registration or other source; and
- additional information.

4. Other information that may be shared

Other information may be collected regarding conditions within the airspace which are impacting the ability to utilize the airspace. This information may be collected by the UA and shared with the UTM system or from other sources. This is not related to failures or shortcomings of the UTM and ATM systems, but rather impacted by external forces (e.g. local weather, airspace hazards, other aeronautical information). There was no clarification made regarding the validation of the information, and how to assess the potential for error and the impact on the system.

For example, weather information may be collected from external providers or sensors on a UA and shared. This may differ from the current practice where meteorological information is provided by certified providers. Other examples of shared information could include geospatial information, which may differ between UTM and ATM.

Where a UTM system is established within a volume of airspace that does not require manned aircraft to be cooperative (e.g. using a transponder or ADS-B Out), this could result in no data being exchanged in relation to that aircraft. Alternatively, the manned aircraft may be cooperative, but there may be no flight plan information available. In such cases, States should consider what alternative requirements are necessary to enable the safe integration of manned aircraft and UA.

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