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

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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 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 command and control 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).

Identification.** The situation which exists when the position and identity of an aircraft is known.

Note.— The term aircraft includes unmanned aircraft.

Lost C2 Link. The loss of C2 Link contact with the unmanned aircraft such that the remote pilot can no longer manage the aircraft's flight.

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 command and control links 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

AGL	Above ground level
AIP	Aeronautical information publication
AIS	Aeronautical information 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
E-ID	Electronic identification
FIMS	Flight information management system
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
RPA	Remotely piloted aircraft
RPAS	Remotely piloted aircraft system
UA	Unmanned aircraft
UAS	Unmanned aircraft system(s)
UTM	UAS traffic management
VFR	Visual flight rules
VLOS	Visual line-of-sight
WRC	World Radiocommunication Conference

Foreword

Over the last ten years, technological development in the unmanned aircraft (UA) industry has disrupted aviation, introducing enhanced capabilities at an unprecedented speed. 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 in 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 flight intents available to UAS operators directly or through a UTM service provider. 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 held its first DRONE ENABLE symposium in September 2017, in Montréal, Canada. 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.

With 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 or remotely piloted aircraft (RPA) operating within the traditional air traffic management (ATM) system.

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. 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); radio spectrum (availability, suitability, security, etc.) and cybersecurity. Like the technology, this document will be updated as developments occur and system capabilities have been demonstrated.

Although the interoperability of certain elements of UTM with ATM and ATC is a critical aspect, this issue will be addressed in future editions of this framework. There are also several components of a safe and effective UTM system that may not be addressed in this edition, such as transitions between UTM and ATM, design and certification standards of the UA and potentially high-altitude airspace UTM systems. 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 emerging UAS sector offers many opportunities, but to be fully integrated, UA will need to coexist with manned aircraft and the 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. Privacy, security, reliability and the environment are also of high public interest. UAS operations must be seen by the public as compliant and accountable if routine operations are to be accepted. Each depends on the harmonization of risk- and performance-based regulations and oversight, including with emerging technological solutions.

UTM systems are therefore envisaged to be interoperable and consistent with existing ATM systems in order to facilitate safe and efficient operations. Although systems-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 structure that remain applicable when considering 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 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, etc.

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 including emerging technological solutions. These frameworks include, but are not limited to:

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

- CAAs optimize the use of common and shared airspace and the radio frequency spectrum.

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

- CAAs or regional safety oversight organizations prescribe and promote, where required, appropriate education, guidance and usage standards for UAS operators and UTM service providers.

- Consistency should be emphasized 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.

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

- The UTM system and UA operated within the system should use 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 fit 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 architecture 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 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, but are not limited to, 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 and 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 airspace authority or ANSP 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 Notices to Airmen (NOTAM).

- 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).

- Separation service

    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 situational awareness 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

ANSPs anticipate that UAS operations will encompass everything from operations that are fully contained in uncontrolled airspace to those that require transit across the boundary between controlled and uncontrolled airspace or that originate and operate 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 over 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 spectrum, resilience and cybersecurity.

Gaps

This section includes a short description of the gaps that must be addressed to enable safe UAS operations within the UTM system.

- 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 encompasses the potential modification of current classes of airspace to include new flight rules applicable to UAS conducting VLOS and BVLOS operations or potentially creating new classes of airspaces 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).
- ICAO Annex 2 **—** *Rules of the Air.* The rules of the air specify 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.
- Operational procedures. Procedures specific to the UTM system, including normal, emergency and contingency scenarios, are needed.
- Liability. Liability and insurance implications for UTM service providers in relation to UAS operators must be determined.
- Certification. 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.

- 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.

Issues

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

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

Challenges

Aircraft participating in the UTM system must be separated from each other and from other hazards (e.g. buildings or 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 (e.g. buildings or weather);

- methodologies to allow improved or enhanced detectability and conspicuity of UA by manned aviation;

- assignment of responsibility for 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;

- determination of the relevant surveillance capability for the UTM system to support the integration of new or novel aircraft and operations; and

- development of policies to address means of compliance or system approval for UTM systems.

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.

This framework document contains three appendices synthesizing information gathered from the submissions to ICAO's Request for Information (RFI) and material provided during ICAO's first DRONE ENABLE symposium.

KEY TECHNICAL AREAS

APPENDIX A

REGISTRATION, IDENTIFICATION AND TRACKING

Presentation review

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.

The ICAO UAS Advisory Group 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 but were not limited to:

- cybersecurity;
- communications and 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

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.

Spectrum requirements

The International Telecommunication Union (ITU) plays a decisive role in allocating protected 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 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, spectrum sharing will be especially vital for urban areas, where operations will be significantly more congested than in rural or remote areas. The 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, spectrum availability or resilience to interference will need to be addressed.

KEY TECHNICAL AREAS

APPENDIX C

GEOFENCING-LIKE SYSTEMS

Presentation review

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 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:

- static: when the data provided to support the geofencing/geoawareness function 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 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 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:

- AIS and GIS data that could be uploaded in a given State (e.g. ATM-related formats such as the Aeronautical Information Exchange Model (AIXM) 5.0 could be utilized).

- Data exchange protocols for the provision of dynamic information on real-time airspace availability or airspace restrictions should be established.

- 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.

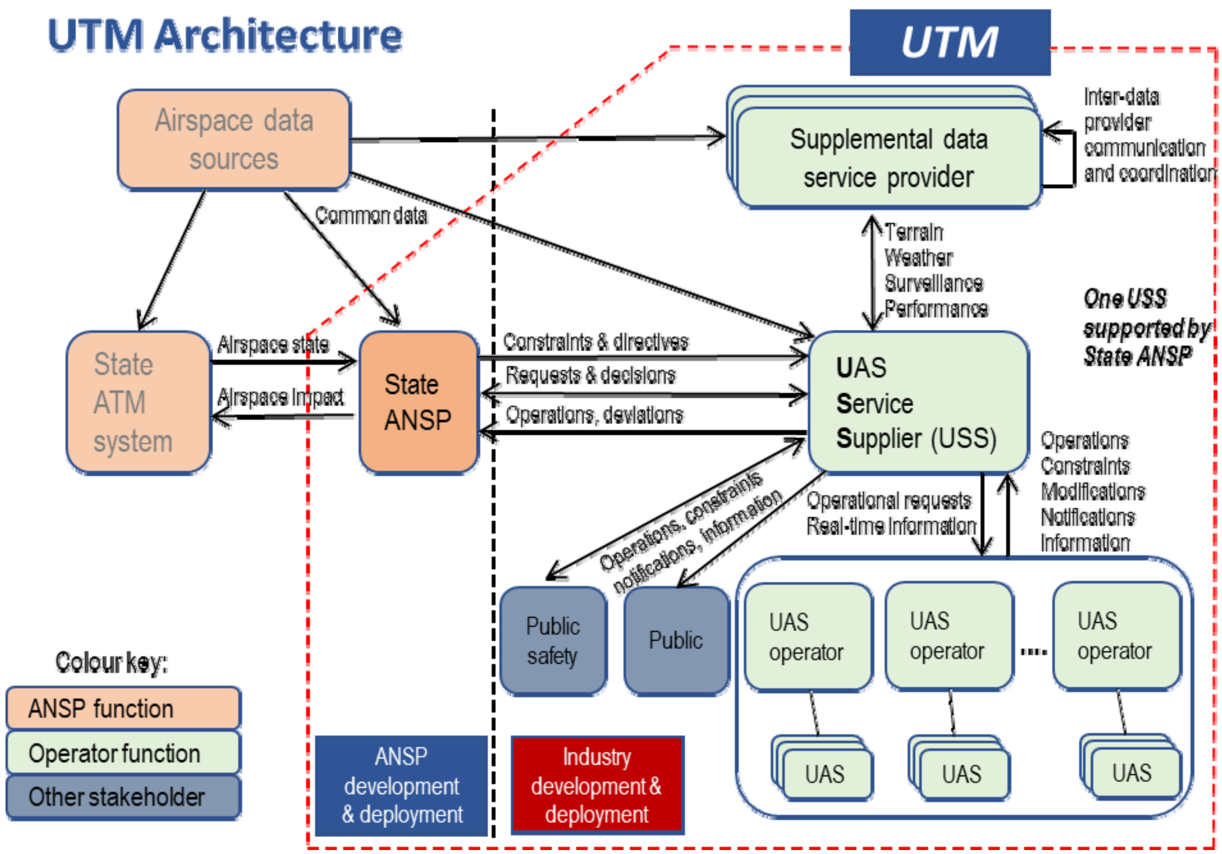
- Anticipated behaviours of a UA when approaching a geofenced area (land, hover, wait for remote pilot instructions, return to home, circumnavigate, etc.) must be identified and system responses developed.

- 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
Public Security Agency
State Server
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

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