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

Edition 3

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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.

Remain-well-clear. The ability to detect, analyse and manoeuvre in order to ensure that a UA is not being operated in such proximity to other aircraft as to create a collision hazard.

Remote pilot.* A person charged by the operator with duties essential to the operation of a remotely piloted aircraft and who manipulates the flight controls, as appropriate, during flight time.

Remote pilot-in-command.* The remote pilot designated by the operator as being in command and charged with the safe conduct of the flight.

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).

Situational awareness.* The ability to keep track of the prioritized significant events and conditions in the environment of the subject.

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 (UA). An aircraft intended to be operated with no pilot on board.

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
AIRAC	Aeronautical information regulation and control
AIS	Aeronautical information service
AIXM	Aeronautical information eXchange model
ANSP	Air navigation services 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(s)
FIS	Flight information service
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
SDSP	Supplemental data service providers
SWIM	System-wide information management
TLS	Target level of safety
UA	Unmanned aircraft
UAS	Unmanned aircraft system(s)
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 soon surpass the number of manned aircraft operations. 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 of technological advancement and the increasing use of off-the-shelf components pose 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 (e.g. artificial intelligence, automation, and robotics) renders any attempt to use traditional methods of certification and operational approval impractical. To meet demand, States and regulators are being innovative and proactive in facilitating and approving such proposals; however, without sufficient international harmonization, this 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 provide real-time information regarding airspace constraints and the intentions of other aircraft available to UAS operators and their remote pilots directly or through a UTM service provider[1] (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), USP, supplementary data service providers (SDSP), UAS operators, remote pilots 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, States and the aviation industry 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 Symposia, to assist in providing direction and guidance in support of harmonizing UAS regulatory activities across 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. To achieve this, ICAO is leading efforts by States, UAS industry leaders, academic institutions and aviation professionals towards the development of this framework for UTM.

This framework provides the foundations for consistent rules and regulations, facilitates consensus on best practices and standards, and supports the development of common guidance material, consistent with the principles laid out in the Preamble to the Chicago Convention (1944):

> "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

[1] A USP is an entity that would assist UAS operators with meeting UTM operational requirements that enable safe and efficient use of airspace, through the provision of UTM services.

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.

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 air traffic management (ATM) system in the short term and integrate with the ATM system in the long term. The introduction and management of unmanned traffic as well as the development of associated UTM infrastructure should not negatively affect the safety or efficiency of the existing ATM system. A common framework is needed to facilitate the harmonization between UTM systems globally and provide a stepped approach towards integration into the ATM system. This would 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 perhaps 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. This document will be updated as technological developments occur and system capabilities are further demonstrated.

While this document continues 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. 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, integration of UA operations in ATM and potentially stratospheric operations. It should be noted, however, that future editions of this framework may address these issues, building on the foundation established by previous editions of the UTM Framework as well as the information gathered by ICAO through the UTM request for information (RFI) process related to the DRONE ENABLE symposia.

For the purposes of this guidance material, in the immediate/near term UTM is considered a separate system with an interface to ATM, while in the long term, integration and potential convergence with ATM is seen as a realistic solution. However, to achieve complete integration, significant standardization issue will have to be addressed.

UTM Principles

The aim of UTM is 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. Like ATM, a UTM system would provide 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). Other issues are important from a societal acceptance perspective, such as privacy, security, reliability, environmental protection and the appropriate use of automation; however these are not addressed in this document. UAS operators must prove compliance with a minimum set of safety standards and be operationally and legally accountable if routine operations are to be accepted by the public. Each of these issues 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 are applicable to UTM services. The following principles should be considered:

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

2. Existing policies for aircraft prioritization, such as aircraft emergencies and support to public safety operations, should be 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/performance requirements and processes defined for the specific airspace in which UTM operations are proposed.

4. The UAS operator and/or the remote pilot should be qualified to perform any applicable normal and contingency operating procedures based on the specific class of airspace in which operations are conducted and on the UTM services being provided.

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

6. In order to achieve an effective UTM capability, the creation, adoption and maintenance of safety culture among the UTM community is essential.

7. The free and open reporting of accidents and incidents should be facilitated for all stakeholders.

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:

1. types of UA and their performance characteristics (including navigation capabilities and performance);

2. adequacy and complexity of the existing airspace structure;

3. spectrum availability and suitability;

4. nature of the operation;

5. type and density of existing and anticipated traffic (manned and unmanned);

6. operational capacity of the UTM system including any airspace constraints;

7. levels of and extent of automation capabilities in the UTM system and in the UAS;

8. regulatory structure;

9. meteorological considerations

10. the requirement for all UA in the UTM airspace volume to be cooperative;

11. detection/separation of non-cooperative UA;

12. management of aeronautical information service (AIS)/aeronautical data, and

13. geographic information systems (GIS) data/additional geospatial 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 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 and/or the remote pilot 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 as well as on the risk of operations and level of resiliency needed. Said services may require compliance with minimum performance requirements/standards. Operational concepts have shown that these services may be provided by third-party USPs, 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 and remote pilots, 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 Doc 9854 — *Global Air Traffic Management Operational Concept*), including, inter alia:

    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 remain well clear of manned aircraft.

c. Conflict advisory and alert service: a service that provides remote pilots 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 or remote pilot.

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.

- Identification service: a service that makes it possible to identify an individual UA and the associated nationality and registration information. See Appendix A for additional information.

- 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.

- Meteorological service: a service that provides individual UAS operators/remote pilots or other UTM services with the meteorological information necessary for the performance of their respective functions.

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;
- a 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, C2 Links or data links associated 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 the creation of 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.
- *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.
- *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 data standards (e.g. data quality specifications, data protection requirements) and protocols to support UTM safety-related services and the exchange of data between UTM and ATM systems as well as between multiple UTM systems are needed.

- *Positional references*. Common altitude, navigation and temporal references for manned and unmanned operations are needed. Gaps in the use of reference points and equipment providing different levels of accuracy and performance in the measurement of altitude, navigation or time introduce safety concerns which must be resolved. Determining the extent to which traditional aviation standards can be used remains a work in progress. Traditional standards which address the provision of such references should be utilized whenever possible.

- *Interface between UTM and ATM*. There is a need to develop procedures and adequate tools to ensure the sharing of information, 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 and aircraft flight recorder requirements, are needed to support accident/incident reporting and investigative requirements.

- *Communications*. Remote pilot interfaces as well as capabilities and performance requirements 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 as well as the restoration of systems after such degradation or failures.

- *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 and performance 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 accuracy, resolution, integrity, timeliness, completeness, traceability, format) 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.
- forecasting and dissemination of micro-weather to address localized weather patterns that may impact low altitude UA operations (e.g. urban canyon phenomenon, wind shear, diurnal effects caused by urban structures, etc.).

Summary

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 3 of this framework document contains eight appendices synthesizing information gathered from the submissions to ICAO’s 2017, 2018 and 2019 Requests for Information (RFI) and from material provided during the respective ICAO 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 by 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, while 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 remote pilot/UAS operator to systems registering everything about the aircraft, UA control station, operator, remote 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 a remote pilot 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).

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)[2], are being considered to support such aircraft-to-aircraft operations.

[2] 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.

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 for reasons including, but 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 Products, 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 and remote pilots. 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. Aeronautical data and additional geospatial data for the UTM system must be quality-assured and provided 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.

KEY TECHNICAL AREA

APPENDIX D

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 centre 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. While ATM functions with a well-established and proven safety management system, 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.

Presenters also outlined the complex gap between responsibilities of UTM and ATM. The gap has materialized as 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, whereas established ANSPs are regulated and follow well established procedures.

Besides the gaps 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 of the presentations at DRONE ENABLE 2 addressed 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, and other situations when they will only operate in close proximity to that boundary. In both cases, 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. Although UTM and ATM have the same objectives (i.e., to prevent collisions and enable safe and efficient operations in the airspace) there are significant differences in the ways by which UTM and ATM may achieve them. 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.

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 stakeholders (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 apply equally 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 E, Essential Information Exchange between UTM and ATM Systems, for more information on information exchange suggestions.

A phased approach is suggested in order to integrate manned and unmanned 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 or remote pilots (e.g., aircraft characteristics of speed, size and manoeuvrability) 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:
    a. for transitioning between UTM and ATM;
    b. to allow traffic under UTM control to operate in an ATM environment and vice versa; and
    c. 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 E

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 regarding 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 Meteorological 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, data quality requirements, data exchange protocols, cybersecurtiy standards as well as system interoperability and system performance requirements. It is also necessay for Stats to define quality requirements for the services supporting UTM-ATM information exchanges.. 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)[3], may be beneficial when addressing SWIM related issues.

[3] In preparation.

Elements of Information Exchange

1. <u>Service Provider Considerations</u>

- Airspace

  Airspace is usually defined and classified by States, with boundaries relating to geographic 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, NOTAMs or perhaps an alternative means of providing real-time updates.

  Future information exchange such as dynamic geofencing 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 quality, 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 UAS operators or remote pilots (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 deconfliction of aircraft between UTM and ATM.

- Tactical coordination and deconfliction:

  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 deconfliction 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. <u>Considerations for information exchange between systems</u>

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)
  a. Electronic identification
  b. Ownership information
  c. Operator contact information
  d. Remote pilot contact information
  e. State of Registry and State of Operator
  f. Aircraft type
  g. Aircraft category (e.g. aircraft, rotorcraft, glider, vertical take-off and landing (VTOL), hang-glider).
  h. Wake turbulence considerations
  i. 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), whether the aircraft carries 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 navigation 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 state 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 or service provision - how is the UA linked to the remote pilot station;
- C2 Link state - 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 that impact 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 impacts by external forces (e.g. local weather, airspace hazards, other aeronautical information). There was no clarification provided regarding the validation of the information, or 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.

KEY TECHNICAL AREAS

APPENDIX F

UTM SERVICE PROVIDERS (USP) ORGANIZATIONAL CONSTRUCT AND APPROVAL PROCESSES

Presentation review (from DRONE ENABLE 3)

Presentations clearly demonstrated that States do not all share a common vision of how to organize and manage UTM Service Providers (USP), or even if or how to enable multiple USPs to operate together in the same airspace. All agreed that CAAs have the responsibility to oversee the provision of services provided by third-party service providers, whether there is one or many USPs.

States are already providing UTM solutions with various levels of service (e.g. registration, identification and environment data), but the full capabilities, responsibilities and roles still need to be clarified and harmonized.

Presenters showed a number of perspectives on the development and ownership of supporting infrastructure.

Technology development is rapid, and any overall systems design should therefore be performance-based, with safety provided through appropriate oversight.

Introduction

This appendix aims to provide guidance to States, regulators and industry on specific elements that need to be considered to enable safe and effective UTM service provision by one or more USPs. Due to the uncertainty of how USPs will be organized and what the overarching governance structure will be, the list of elements cannot be exhaustive or suitable to all possible scenarios.

Recognizing the possible alternative approaches to organizing USPs, this appendix makes no assumptions about a preferred architecture, governance model or business model. To achieve this, the document is structured as follows:

- The first section looks at high-level concepts that should be common to all USPs, regardless of which UTM service provision implementation model is preferred, enabling USPs to operate in a consistent and interoperable manner.
- The second section goes more deeply into the different architectural options, linking the differences to the concepts raised in the first section.
- The third and final section looks briefly into the future, suggesting how initial implementations should evolve in the interest of greater global harmonization.

Common High-Level Concepts

This section introduces concepts that should be common to all possible implementations of UTM service provision, and covers the following three aspects:

- Criticality of services;
- Approval and oversight; and
- Interoperability.

Criticality of services

Operational experience from both ATM and UTM show that some services have a greater degree of criticality than others. For example, safety-critical services will have a higher degree of criticality than some supplemental services, such as meteorological data. It was widely agreed that services with a high degree of criticality would need a greater degree of oversight and that such services may need to be provided centrally. Nevertheless, not all presenters agreed on which services should be categorized as 'critical', or on the mechanism for performing such assessment.

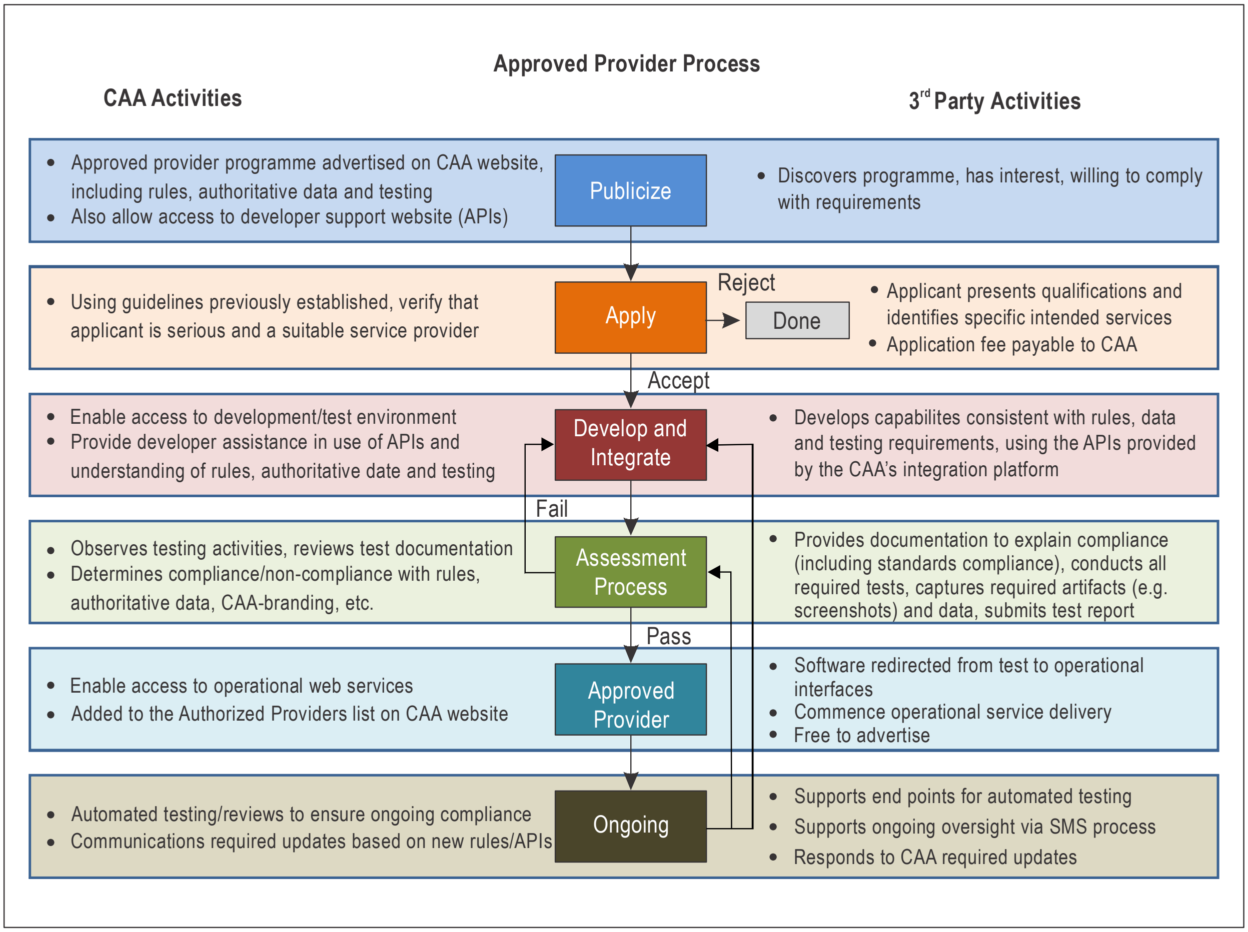
It is therefore proposed that each State perform an analysis to determine the criticality of the various UTM services that are intended to be delivered in that State, and to specify those services that must, according to that State, be provided centrally, if any. UTM services could be allowed to be provided by one or more USPs in the same airspace volume, under the oversight of the State regulator. This analysis should also determine which services are considered to be mandatory, that is those services that must be provided in order for effective UTM service provision.

Safety should be the principal consideration to identify critical services, such as those that provide for safe cooperation with manned aviation, but other factors may also be considered as important, such as security. Individual States may apply their own criteria to identify critical and non-critical services.

Approval and oversight

The regulator retains the ultimate responsibility for its oversight role, although certain tasks could be delegated to appropriately-approved bodies. The regulatory structure should enable the effective cooperation with manned aviation, showing how UTM service provision affects and supports both manned and unmanned operations. Regulations should also clearly show how airspace is to be managed, leaving no ambiguity about what kinds of UTM service can be provided where, and detailing any conditions for UTM service provision in any given class of airspace.

Policies need to be produced that clearly show who is responsible for each UTM service, whether centrally provided or not, and how each service should be provided. This should include performance-based requirements for USPs that enable an effective USP approval and accreditation process to be implemented. As far as possible, the mechanism for approving USPs should be harmonized, allowing recognition of USP certification between authorities, thus promoting consistent application of UTM service provision and reducing costs and complexity. The figure below shows an example flow-chart of a process for approving and monitoring a USP.



The needs of the military and security communities must be taken fully into consideration, by both regulator and service provider, with clearly defined mechanisms for ensuring the delivery of UTM services that assure the safe management of UA operations alongside manned and unmanned military and security aviation. This should include mechanisms for determining and applying prioritization, depending on the circumstances. Such prioritization should address both conflicts between UA and between manned and unmanned aircraft. The existing priority mechanisms used in manned aviation, including medical and emergency situations, should be considered as a starting point.

Processes for the approval of UA flights are complex and involve more than just aviation stakeholders. Regulations should also cover interfaces between USPs and non-aviation stakeholders, such as city authorities.

Some data used in the provision of UTM services could be business or mission critical, and may therefore be highly confidential. Regulation, system specifications and processes should ensure the respect of that confidentiality by USPs.

<u>Interoperability</u>

As far as possible, implementation of UTM should be based on standards produced and agreed by international standardization bodies. These standards should only be prescriptive where essential; performance and risk-based standards allow for the introduction of new technologies and promote innovation while supporting safety and interoperability.

In order to ensure a consistent level of performance of service provision, service level agreements (SLA) will need to be established between UAS operators and USPs. Although many such SLAs will be commercial, there will be some that relate to the delivery of certain non-critical services. For these services, the minimum level of performance could be defined through an SLA, rather than through more prescriptive standards or other more formal specifications.

The key mechanism for ensuring interoperability between USPs is through effective data exchange. USPs will process an extensive range of data from many different sources, and the quality requirement for each type of data should be specified and standardized. Detailed considerations for data exchange between UTM and ATM can be found in Appendix E, and many of these apply equally to exchange between USPs, including the adoption of SWIM principles and data exchange models (AIXM, FIXM and IWXXM). Where additional data exchange requirements are identified between USPs, the same principles as those described in Appendix E will largely apply. However, for some non-critical exchanges between USPs, the level of quality assurance needs to be commensurate with the level of criticality in order to reduce costs and to simplify the oversight processes; this determination will need to form part of the definition of each affected service.

The industry approach to enabling multiple USPs or/and SDSP into a UTM ecosystem has mostly taken the form of APIs. The case for interoperability, however, goes beyond APIs to include a common communication language and requirements on the core information to be shared within the UTM ecosystem. Initial considerations for establishing a common communication language (or data model) include, inter alia, the type of information to be shared, the quantity of data that would be transmitted across the ecosystem, acceptable latencies involved, immutability of the data and the constraints of current and future technologies for processing this data (transmission and translation). To establish specific requirements related to these considerations, there is a need to establish what information is exchanged and how it would be used, and the mechanism(s) by which it would be exchanged, including whether human intervention is necessary or whether it is fully automated.

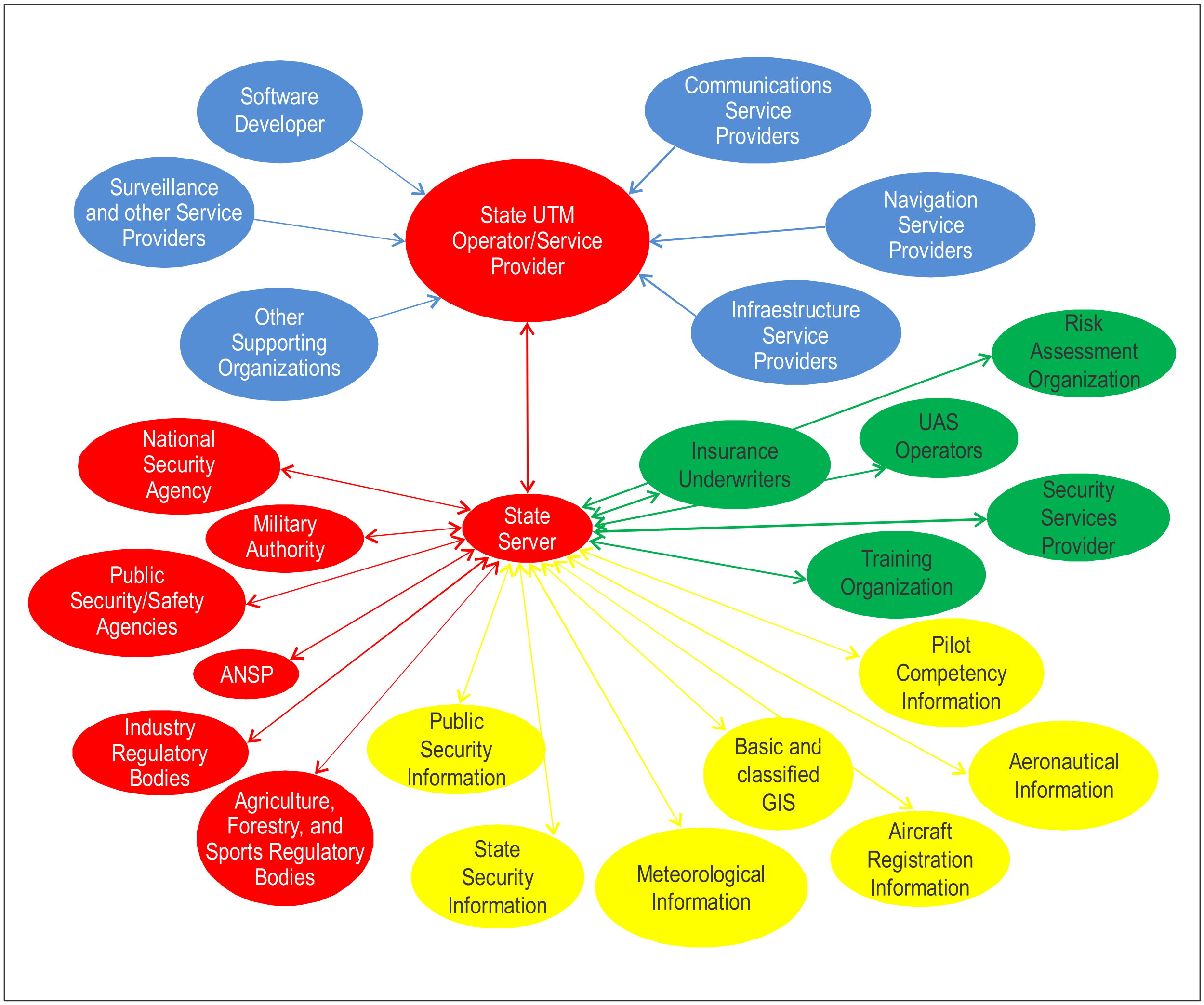
One of the historical issues found in the manned aviation environment stems from the use of point-to-point data connections and third-party equipment for enabling connections between two systems supported by hardware-specific APIs. This has provided a level of security but has reduced the ability for data-sharing beyond those systems and introduced cumbersome software maintenance needs; in some instances, it has inhibited the ability of service providers to integrate new systems or services. The opportunity for the UTM ecosystem is to develop a network-centric environment where information can be shared with multiple entities in a timely manner, and for new USPs or SDSPs to be more readily connected, removed or replaced.

Different approaches to implementation

It is not the intention of this appendix to dictate any particular architecture, but it is clear that different architectures will lead to some differences in implementation. In order to promote consistent application of the principles described above, this section describes two models currently being implemented and considers their application within each model. Although only two architectural models are considered here, there are several others, but this illustration should allow applicability to other models to be determined.

The two example architectural models are shown below. The two example architectures are: centralized service provision and federated services provision.

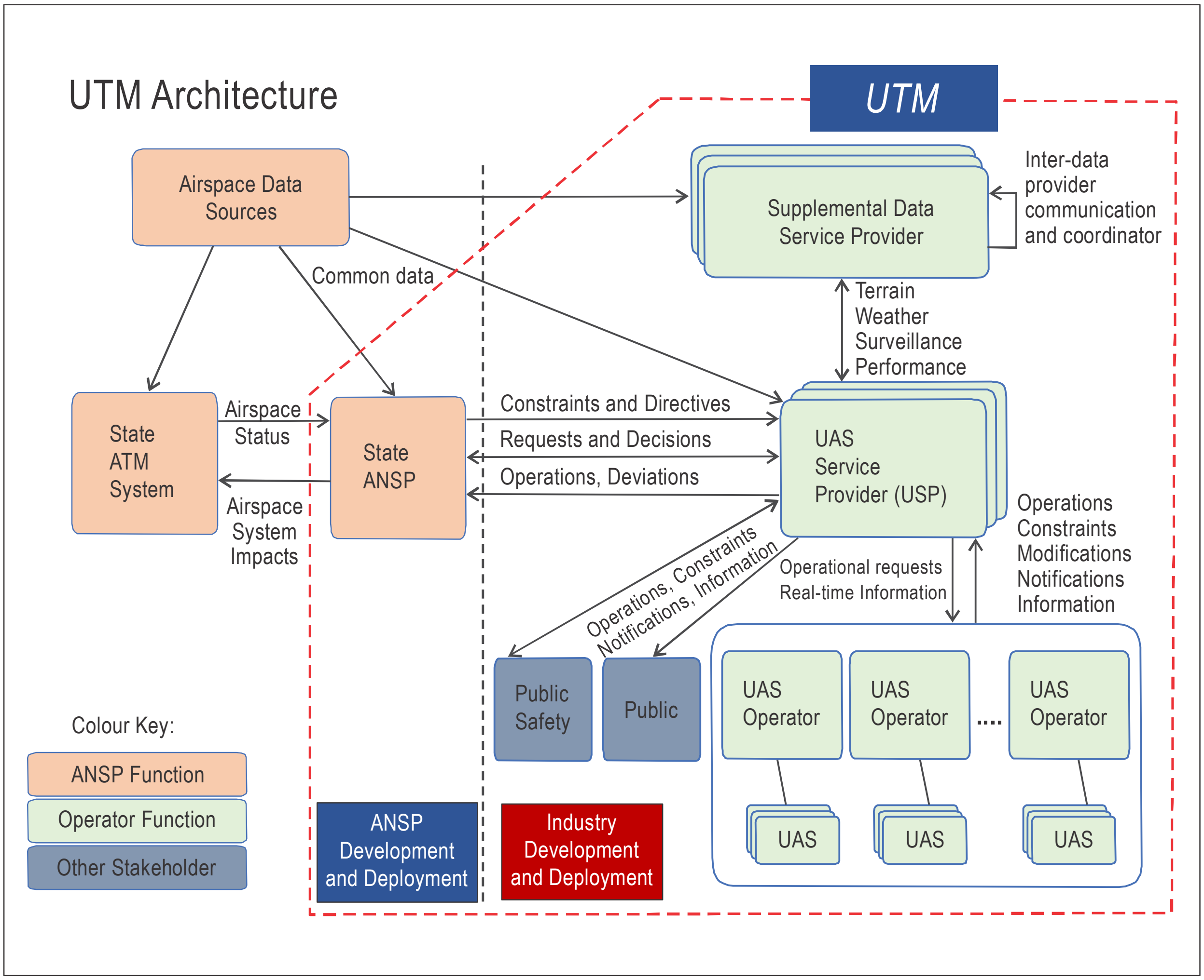
<u>Centralized service provision</u>



In a centralized architecture, a central agency can be responsible for all aspects of service provision, either through direct provision of services, or through coordinating the actions of other service providers. In this case, the 'State Server' represents the authority to which all other stakeholders report. This is usually the CAA, undertaking its role as regulator. One of the many links is shown as being to the ANSP, which is regulated in the traditional manner.

In the upper part of the diagram, a link is shown to the 'State UTM Operator/Service Provider', which then links to other providers involved in the delivery of UTM services. This model shows a reproduction of the traditional ATM structure in UTM, with a single, State USP responsible for delivery of UTM services, although it could be supported by SDSPs. It should be noted that, in its purest form, in a centralized architecture there will be one SDSP for each service provided.

<u>Federated service provision</u>



In this example of a federated architecture, there is still one central regulator, functionally the same as for the centralized model. Similarly, in this example, there is also a single State ANSP. The difference comes in the relationship between the regulator, the ANSP and the USPs.

In a federated architecture, a USP provides UTM services, but is no longer a State entity, and nor is any USP unique. All USPs are regulated by the State regulator and have clearly defined responsibilities with regard to the ANSP. In line with this appendix, there is also the need for the relationship between USPs to be precisely defined.

Under this model, different USPs could provide dissimilar sets of UTM services depending on their business model, so the interfaces between them may be different. However, the requirements for each UTM service should be applied consistently and in accordance with the standards and regulations.

Future evolutions

With the current state of development, future evolution is set to be rapid, and it will follow paths as yet undefined by stakeholders. In order to support this continued evolution while encouraging innovation, moving from today's assumptions to tomorrow's reality will require:

- Safety assurance for manned aviation, UA and people and property on the ground. This will require a partnership between regulator, service provider(s) and UAS operator, as well as stakeholders new to the aviation domain, such as city authorities, law enforcement agencies, telecommunications providers and suppliers of non-aviation data.

- Flexibility in system architecture and UTM service definition to enable UTM systems to react to developments in technology and business applications. This can only be achieved by making regulations prescriptive only where necessary, while allowing performance and risk-based standards to be used as the mechanism for defining how UTM is implemented.

- Increase in efficiency in UTM service provision, especially as numbers of UA increase, and this will be dependent on a significant increase in automation. This may include the introduction of artificial intelligence and/or machine-learning, both of which would require entirely new mechanisms for standardization and governance. Such development could also benefit the wider aviation community.

- Ongoing harmonization of standards and regulations that support various implementation options. While different States may envisage different implementations, following the principles within this document will promote consistent and interoperable UTM service provision.

- Automatic and continuous validation of UTM systems. This may require the development of a new mechanism for performing such validation, but the pace of development in UTM is such that existing aviation mechanisms may not be able to keep pace. Moreover, it was considered that ANSPs and even existing aviation regulators may not yet have the experience and capability to define such a dynamic validation mechanism. As such it may be necessary to learn from non-aviation domains, and to determine if alternative mechanisms are suitable for aviation purposes.

- New and amended economic and cost recovery models for both the services provided and potentially the regulatory oversight aspects may need to be developed.

Conclusions

Each USP can make use of services supplied by multiple SDSPs, but not necessarily the same ones. Competition may result in there being multiple service providers providing identical services to different customers, both UAS operators and other USPs, all of whom would need to follow the same standards and regulations and be approved to do so by the regulator.

It should be noted that, at a functional level, the two architectures could be considered to be very similar:

- One regulator;

- One ANSP;

- USP governed by the regulator according to regulations, standards and procedures;

- SDSPs providing services to USPs; and

- Defined links between all stakeholders

This being the case, the principles described within this document are equally applicable to all possible architectures, with differences arising solely due to implementation choices. By following the principles of this appendix, a centralized implementation could start to introduce additional USPs at a later date, should that be desired by a particular State.

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KEY TECHNICAL AREAS

APPENDIX G

DECONFLICTION AND SEPARATION MANAGEMENT

Presentation review (from DRONE ENABLE 3)

A key element of any safe separation provision in a UTM will be the definition of a safe distance or a safe time between aircraft. A number of presenters at DRONE ENABLE 3 gave their views on Deconfliction and Separation Management, with the key consideration being how manned aviation principles could be applied to UA and what new principles would need to be developed. This included how to define a target level of safety for UA, and the different dependencies that need to be taken into consideration.

While it is anticipated that deconfliction and separation will be managed through an automated system using algorithms, many fundamental questions are still to be decided. In this process the effects on all stakeholders and the operating environment need to be taken into account. Among others, careful airspace planning and flight route optimization will enable strategic deconfliction solutions. Tactical deconfliction solutions will increase complexity and the need for system resources, especially with the anticipated high numbers of UA. It was also noted during various presentations that effective separation and deconfliction requires traffic to be cooperative. The issue of non-cooperative traffic was not addressed during these sessions.

As aircraft equipage is a fundamental element of any target level of safety definition, special care must be taken to select the right equipment and system requirements. These requirements can range from traditional communication, navigation and surveillance to assessing new parameters.

Introduction

States and industry are seeking an integrated operating environment in which manned and unmanned aviation can operate in a safe and efficient manner. Previous UAS operations have been generally intended to be segregated from manned aviation through the use of restricted airspace, or advice to other aircraft through notifications such as NOTAM of the location of unmanned operations. While segregated airspace has been an initial solution to accommodate a safe operating environment, it does not enable future integration of manned and unmanned aviation, nor does it enable high density UAS operations.

Global Air Traffic Management Operational Concept (Doc 9854) states that conflict management will consist of three layers: strategic deconfliction, separation provision (tactical deconfliction) and collision avoidance. These principles from manned aviation can be applied to UA deconfliction and separation management. However, not all will be applicable to unmanned aviation in the same way, and there is a need for the consideration of new methods for managing air traffic. Different technology is likely to be required to manage the large volume of UA traffic predicted, particularly in urban environments. The appropriate methods of conflict management need to be determined between both manned and unmanned aircraft, as well as between unmanned aircraft.

Target Level of Safety (TLS)

Target levels of safety are being applied in manned aviation conflict management and these vary depending on a number of factors, including the specific operation. Likewise, appropriate target levels of safety will need to be determined for unmanned aviation which will take into consideration the airspace and the mix of traffic in that airspace. The level of safety can be impacted by a number of variables, including type and density of traffic, aircraft and system performance, equipage, aircraft speed, type of operation and human and machine interventions available. Depending on the various factors, a safe distance or safe time between aircraft must then be determined to reach the desired TLS. In addition to the factor listed above, others (e.g. pre-flight planning, weather, etc.) should be considered when determining the overall TLS of a UTM operation.

Strategic Deconfliction

Strategic deconfliction is seen as a fundamental UTM service required to enable unmanned aircraft flights. It is the most predictable layer of conflict management and is usually applied in the pre-flight and pre-tactical phase of operations. Through dynamic airspace management, UA may also be affected on a tactical level.

Airspace organization is the primary method of strategic deconfliction. ICAO airspace classifications for different volumes of airspace take into consideration density of air traffic, types of operations and requirements for aircraft equipage. It is envisaged that similar principles may be applied in a UTM environment. This could determine if the remote pilot-in-command, or potentially the UAS operator, is responsible for deconfliction, or if a deconfliction or separation service is provided.

One solution presented is to divide the airspace into low-, medium- and high-risk volumes which then determine the service required. However, managing the airspace design will be much more complex than that of ICAO airspace classes. Airspace (re)classification for UAS operation may not be directly compatible with the current ICAO airspace classification. This could lead to a situation where the same volume of airspace is managed by an ANSP and USP(s) simultaneously. Each service provider would serve its respective clientele. This may require both manned and unmanned aircraft to have certain equipage to comply with ATM and UTM requirements, or unmanned aircraft to satisfy manned aviation airspace requirements. With appropriately defined ATM-UTM boundaries and integration, it is anticipated that manned aviation equipage requirements for ATM will also meet the UTM requirements.

Several presentations identified the need for demand and capacity balancing, which is usually achieved by analysing filed or predicted flight plans and adapting them. In a UTM environment this will typically be achieved by an automated function. Strategic deconfliction through (re)routing or careful definition of airspace volumes might increase flight time. It may also be dependent on other factors such a signal coverage, dynamic or permanent airspace restrictions, mission type, weather and energy available.

Proactive conflict management using the above-mentioned principles might require less computing and communication resources and result in more regular traffic patterns with high reliability, balancing improved safety with decreased flexibility.

Manned aviation works on the principle of barometric pressure measurement for altimeter indication, whereas UAS often rely on GNSS height or altitude or a barometric altitude measurement above a certain reference point (e.g. take-off position or position of the remote pilot station). Altitude and height discrepancies between manned and unmanned aircraft resulting from different reference points, methods of measurement as well as altimeter inaccuracies increase the risk of collision. Consequently, mitigations such as a common reference system or an automatic altitude correction method need to be considered.

Tactical Deconfliction and Collision Avoidance

Tactical deconfliction, the provision of a safe distance or safe time between aircraft in flight, can be achieved by a UTM service, the remote pilot and/or an automated remain-well-clear function on board the UA. This will depend on the actual airspace requirements and the combination of the three aforementioned elements.

The above is not to be confused with collision avoidance function of the UA, as a last safety barrier. This collision avoidance function is not considered for the calculated level of safety.

The provision of a tactical deconfliction service by the UTM system, which is reactive conflict management, may require sophisticated technology and a high amount of computing and communication resources, especially in high density traffic situations and in complex traffic patterns. This could lead to lower predictability and reliability of flight paths while allowing for a higher flexibility in operations.

	Demands for computation resource	Demands for Communication resource	Resulting traffic pattern	Reliability	Flexibility
Reactive	High	High	Highly complex, unpredictable	Low	High
Proactive	Low	Low	Regular, predictable	High	Low

To facilitate the provision of these services, aircraft tracking, traffic monitoring and information sharing must be available.

It can be assumed that certain parts of the airspace with a low density of traffic will require less rigorous aircraft and UTM system performance requirements. UA may be permitted to self-separate using on-board detect-and-avoid technology or alternatively remote pilots may navigate according to information received by the UTM or visual acquisition.

While manned aircraft are provided with a certain amount of separation in the vertical, lateral, longitudinal and temporal dimensions depending on flight rules and airspace, this has not been defined for all categories of UAS yet. It can be expected that the safe distance or safe time between two aircraft will depend on the performance requirements and abilities of the aircraft and the UTM system, with the amount of separation also dependant on flight rules and airspace. This could then be incorporated into the operational volume of the UA.

Separation standards are calculated using extensive collision risk modelling based on assumed and real data and use cases. The collection of sufficient and usable operational data for UAS operations is required to support ongoing risk modelling. Once the target levels of safety for UAS operations or airspace are developed, it will be important to monitor the actual performance of aircraft to ensure that the TLS is in fact achieved.

It cannot be expected that manned aircraft pilots will be able to efficiently separate themselves from UA. It is therefore critical to ensure that the UAS and/or the UTM system have awareness of the surrounding traffic, including both manned and unmanned. How this awareness is accomplished can be different for the UAS and the UTM system where the UAS maintains awareness of surrounding traffic at that instant while the UTM system may offer that as well as intent.

A careful assessment of the necessary balance between the needs for strategic and tactical deconfliction must be made in order to get the best outcome in terms of system requirements and user needs, maintaining the desired TLS.

Gaps, Issues and Challenges

The deconfliction concepts presented raise a number of gaps, issues and challenges which include, but are not limited to:

- Priorities: how is access to airspace regulated and who receives priority? The concepts of “first come, first served” or “best equipped, best served” may not be the most appropriate ways of prioritizing aircraft. Other variables such as the mission of aircraft and whether people are on board may be a factor.

- Impact on flight route: what change in route will be acceptable to successfully accomplish the mission? Is there a negotiation process between the UAS operator and the USP and how is it resolved?

- Safety buffers: what buffers are required to the airspace or route? What is the impact of the mission, aircraft type, performance, equipage, etc. on these buffers?

- Applicable time requirements: are there specific time requirements for when strategic deconfliction processes need to be initiated and/or completed?

- Do the same requirements that apply to manned aircraft regarding when strategic deconfliction changes to tactical deconfliction apply to UA?

KEY TECHNICAL AREAS

APPENDIX H

UTM RISK ASSESSMENT AND CONTINGENCY PLANNING

Presentation review (from DRONE ENABLE 3)

DRONE ENABLE 3 participants provided information on various risk assessment activities and contingency planning operations. The materials presented mainly came from Exploratory Research & Development projects. Initiatives on UTM, including risk assessment, are numerous, ranging from industry partnership enterprises to State initiatives. Activities involving CAAs and global organizations have allowed safe and successful UAS operations in non-segregated airspace on an ad hoc basis. Currently, these projects are mainly running in a demonstration mode in selected environments and conditions. These projects are key contributors to the development of risk assessment methods, best practices or recommendations.

Several presentations introduced different risk assessment methodologies available, focusing on various types of risks: air risk, ground risk, minimizing probability of mid-air collision, and probabilistic approach (taking into account several different risk factors). Each risk assessment focuses on several risks, but almost all of them are more UA-centric. Other presentations highlighted the need for more encompassing risk assessment methods including other traffic or the environment.

A couple of presentations explained the different nature of contingencies, whether they are UA or UTM related failures. A Contingency Management Algorithm was proposed to help identify, evaluate, mitigate and resolve contingencies related to UTM failures.

Introduction

At the outset, it is recognized that safety is paramount to the use of airspace, regardless of the class of airspace or operation being conducted. The achievability of a certain target level of safety for different airspaces or types of operations are demonstrated by the application of safety methodologies, which include exhaustive risk assessment. It should be noted that the risk assessment process presented in this appendix is not intended to address security risks linked to UTM. However, it must be recognized that cyber security threats could pose risks to the UTM system and traffic within the system, and should be contemplated in a risk assessment (e.g. fake or non-identified UA).

One of the results of the risk assessment is the identification of contingency planning to mitigate the residual risks during possible eventualities.

While UTM services are maturing, in order to achieve integration of unmanned aircraft into non-segregated airspace, the creation and adoption of a safety culture among the UTM community is required.

UTM Risk Assessment Objectives

The objective of a UTM risk assessment is to evaluate the consequences of different types of degradations or failures (of one or several UTM services, systems or processes) in order to validate/verify the desired safety levels and ultimately decrease the risk of an incident or accident. This evaluation will be used to define UTM safety requirements and to develop mitigation procedures at UTM operational, design and implementation levels. In addition, the objective of the UTM risk assessment is to ensure safe integration of UA operations into airspace.

There is a consensus to consider that some UTM services and capabilities are safety critical. These services likely include, but are not limited to, those in charge of managing ground and air risks: geofencing, strategic deconfliction, tactical separation and conflict advisory, alert service and interface with ATC.

Safety-critical services require a thorough risk analysis to identify effective mitigations in normal, abnormal and faulted conditions. Non safety-critical services may also require a risk assessment, but it may not lead to the identification of a mitigation strategy. Nevertheless, the risk assessment is performed in conjunction with taking into account all kinds of services which could influence each other’s performance.

In the UTM risk assessment, the hazards originated from multiple UA operations should be addressed, along with other external hazards such as weather (e.g. micro-weather effects), electromagnetic interferences or GNSS failure or malfunction.

The UTM risk assessment has a holistic approach to analysing multiple UA operations and UTM services. The UTM risk assessment encompasses more than a single UA operation risk assessment. It does not focus on a particular operation and takes into account all possible traffic in an area where UTM services are deployed. Therefore, in order to have a thorough risk assessment, both a UTM and single UA operation risk assessments need to be performed.

In ATM, the human is the key factor in risk mitigation. Such a strategy is not directly applicable to UTM and there is a need to propose new procedures and processes. UTM risk assessment methodology should provide a level of safety equivalent to or the same as the current level of safety in manned aviation when UTM operations are integrating with ATM. In parallel to the UTM risk assessment it is necessary to develop mitigation measures, including contingency planning.

UTM Risk Assessment Challenges

In order to identify challenges associated with risk assessment processes, it was assumed that a combination of regulatory measures, led by States mindful of technological developments, will provide a sufficiently robust framework to enable effective risk assessment. It is assumed that much of the initial risk should be mitigated by the regulatory processes in place while those areas that are not addressed by the regulations would be addressed through the UTM risk assessment process.

As a result of the need to consider both a UTM-centric and a single UA operation view as part of a thorough risk assessment, ensuring that all operations and risks intended to be addressed by a given UTM system can be challenging. Identifying risk assessment methodologies for UA operations and UTM systems is complex at best. Any proposed risk assessment approach must consider both the operations and the environment in which the operations are taking place. Whichever process is used, it is important to ensure that the assessment consider both ground risk as well as air risk. In addition, it is important to identify touchpoints and common elements from the UA risk assessment which could facilitate a UTM-centric risk assessment and vice versa.

All risk analyses have common impediments. Service quality parameters are essential in completing a UTM-centric or a single UA operation risk assessment. Currently service quality parameters have not been clearly defined, making a meaningful full risk assessment challenging. Lack of historical UTM and UA data or data quality will provide a challenge to risk assessments, potentially leading to different mitigations. As more UTM and UA data is collected, optimization of mitigations will become easier. The lack of a defined UTM infrastructure is another factor that makes defining metrics for use in risk analysis difficult. As infrastructure is developed and deployed, metrics that can be used in risk analyses will solidify, however, initial risk analyses will need to be robust despite the lack of metrics.

UTM stakeholders play a key role in the UTM risk assessment. In the current situation, UTM stakeholders need to be identified on case-by-case basis, as a standard list of stakeholders involved has not yet been clearly defined.

As UTM may use a number of functions and services which are automated, this may create an additional challenge during the risk assessment implementation. Automation may also play an important role in future risk assessments.

UTM Risk Assessment Considerations

A UTM risk assessment process should identify which stakeholders need to be involved in each stage of the risk assessment.

A UTM risk assessment should be performed (possibly in limited form) when any change to a UTM system is made (e.g. system updates, introduction of new technologies or services).

A UTM risk assessment needs to be performed for each service (as listed in the main body of the text) that is provided by the UTM system. All elements of the service (e.g. data exchange, business rules) should be included in the risk assessment.

A UTM risk assessment should also address UTM component interfaces. Each interface within a UTM system or between UTM system components and an external service component (e.g. ATM components) should be included in a risk assessment.

A UTM risk assessment should be based on up-to-date data and documented inputs; if any variables or inputs have been changed, the risk assessment should be reviewed.

A UTM risk assessment should be reviewed periodically to determine efficiency of the mitigations and necessary corrective actions should be initiated, if required.

It should be noted that the result of a risk assessment is highly dependent on the environment in which UTM operations are being conducted. For example, the same type of operation in an urban environment will necessarily have a different set of risks than if that operation is taking place in a rural environment.

UTM Contingency Planning

UTM providers should define and implement contingency plans in the event of disruption, or potential disruption, of the UTM system or related supporting services. The objective of contingency planning is to assist in providing for the safe and orderly flow of UA traffic in the event of disruptions of the UTM system and related supporting services. Contingency planning is an important means to mitigate risks.

Contingencies can be UTM-failure related and UA-failure related. This appendix only addresses the UTM aspect. While it is possible that a UTM contingency procedure may affect UA operations, a UA contingency or emergency should not trigger a specific contingency procedure for the UTM system.

States should require USPs to develop a UTM contingency plan. Regulatory and procedural guidance in case of contingency should be developed and made available to all stakeholders.

It should be noted that some differences between UTM and ATM impact how the contingency procedures can be defined. In UTM, there is much less human intervention compared to the ATM system. For example, instead of a human-in-the-loop, automated systems may address localization and isolation of the problems. Therefore new ways to mitigate the risks need to be defined. ATM and UTM may experience some common failures for which similar mitigations might apply (for example an electrical failure).

The number and nature of services provided by UTM impact the content of contingency procedures, the failure of which may also affect ATM (e.g. tactical separation). In these cases, the contingency procedures should be coordinated with ATM.

UTM contingency management may require some overarching management of the entire ecosystem. For example, when more than one USP is providing services in a given airspace, could they provide redundancy for each other?

Each contingency plan is unique and tailored to address the anticipated failures of the specific services provided by the USP. Contingency plans should contain procedures addressing all failures identified by the risk assessment.

A contingency plan could contain all or some of the following elements:

- Purpose and use;
- Policy inputs;
- Legal requirements;
- Roles and responsibilities;
- Contingency principles (safety, continuity);
- Contingency key events (i.e. foreseen contingency situations) and related risks;
- Review of other contingency plans (e.g. ATM);
- Contingency procedures;
- Description of the contingency environment; and
- Summary of the operational impacts and analysis of changes.

USPs may want to use the following process for managing contingencies:

- Recognize the failure;
- Identify the appropriate procedure within the overall contingency plan;
- Initiate measures as per the contingency plan procedure;
- Resume normal operations;
- Assess the effectiveness of the contingency procedure; and
- Update the contingency plan as necessary.

Additional Considerations

The implementation of a safety management system by each UTM stakeholder would help establish and promote the necessary UA safety culture, in line with policies set forth in ICAO Annex 19 — *Safety Management*. Doc 9859, *Safety Management Manual*, provides guidance material intended to assist in managing aviation safety risks and may provide useful information when establishing UTM risk assessment processes.

There are several risk assessment methodologies available, including: JARUS SORA[4] , CORUS MEDUSA[5] , Airbus Altiscope, Safety risk management in conformance with European *Commission Implementing Regulation* (EU) 2017/373, and (SAE) ARP4761 *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*, etc. It should be noted, however, that existing processes and methodologies may need to be modified or tailored to suit the UTM environment.

Currently the safety occurrence reporting requirements are minimal in a UTM environment. States should implement processes to ensure more reporting in order to improve safety, refine risk assessment and build better contingency plans based on real data and feedback.

— END —

[4] Joint Authority for Rulemaking on Unmanned Systems - Specific Operational Risk Assessment (JARUS SORA)
[5] Concept of Operations for European UTM Systems - Method for the U-Space Assessment (CORUS MEDUSA)