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

Edition 4

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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.

Airside.* The movement area of an airport, adjacent terrain and buildings or portions thereof, access to which is controlled.

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).

Landside.* *Those parts of an airport, adjacent terrain and buildings or portions thereof that are not airside, as identified by States and relevant entities in their security programmes.*

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).

Separation provision.* The tactical process of keeping aircraft away from hazards by at least the appropriate separation minima.

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

A-CDM	Airport collaborative decision-making
ADS-B	Automatic dependant surveillance-broadcast
AGL	Above ground level
AIP	Aeronautical information publication
AIRAC	Aeronautical information regulation and control
AIS	Aeronautical information service
AIXM	Aeronautical information exchange model
AMC	Alternative means of compliance
ANSP	Air navigation services provider
API	Application programming interface
ATC	Air traffic control
ATCO	Air traffic control officer
ATM	Air traffic management
BVLOS	Beyond visual line-of-sight
CAA	Civil aviation authority
CDL	Configuration deviation list
CNS	Communications, navigation and surveillance
CONOPs	Concept of operations
DAA	Detect and avoid
E-ID	Electronic identification
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
ISSA	In-time system-wide safety assurance
ITU	International Telecommunication Union
LAANC	Low altitude authorization and notification capability
MEL	Minimum equipment list
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
SHF	Super-high frequency
SLA	Service level agreement
SORA	Specific operational risk assessment
SWIM	System-wide information management
TET	Transaction expiration time
TLS	Target level of safety
UA	Unmanned aircraft
UAS	Unmanned aircraft system(s)
UHF	Ultra-high frequency
USP	UTM service provider
USMS	UAS safety management system
UTM	UAS traffic management
VFR	Visual flight rules
VLOS	Visual line-of-sight

VTOL	Vertical take-off and landing
WAM	Wide area multilateration

Foreword

For over a decade, technological development in the unmanned aircraft (UA) industry has disrupted the aviation industry, 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 UAS operations will include those that are fully contained in either controlled or uncontrolled airspace, and those that transit across these 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) challenges the traditional methods of certification and operational approval. To meet demand, States and regulators are being innovative and proactive in facilitating and approving such proposals; however, without sufficient international harmonization, these efforts 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, when available, to UAS operators and remote pilots directly or through a UTM service provider[1] (USP). The UAS operator would then be responsible for safely managing its operations 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.

At the 39th Session of the ICAO Assembly, in 2016, States and the aviation industry, requested that ICAO urgently address 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 to harmonize regulations for UAS operations outside the international instrument flight rules (IFR) framework. In response, ICAO has assembled industry partners at its annual DRONE ENABLE Symposia, to assist in providing direction and guidance supporting harmonization of 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 *Convention on International Civil Aviation* (Doc 7300), signed at Chicago on 7 December 1944 and amended by the ICAO Assembly:

> "WHEREAS the future development of international civil aviation can greatly help to create and preserve friendship and understanding among the nations and peoples of the world, yet its abuse can become a threat to the general security; and
>
> WHEREAS it is desirable to avoid friction and to promote that cooperation between nations and peoples upon which the peace of the world depends;

[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.

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 one. 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 issues will have to be addressed.

UTM Principles

The aim of UTM is the safe, orderly and expeditious 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:

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

- adequacy and complexity of the existing airspace structure;

- spectrum availability and suitability;
- nature of the operation;
- type and density of existing and anticipated traffic (manned and unmanned);
- operational capacity of the UTM system including any airspace constraints;
- levels of and extent of automation capabilities in the UTM system and in the UAS;
- regulatory structure;
- meteorological considerations;
- the requirement for all UA in the UTM airspace volume to be cooperative;
- detection/separation of non-cooperative UA;
- management of aeronautical information service (AIS)/aeronautical data; and
- 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 that 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 and third parties on the ground. The UTM architecture should also enable 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 complies 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.

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.

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

- 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.

- Conflict management and separation service (please refer to Doc 9854 — *Global Air Traffic Management Operational Concept*), including, inter alia:

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

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

    c. Conflict advisory and alert service: a service that provides remote pilots with real-time alerting on UA proximity to other airspace users (manned and unmanned), and advice on avoiding such users.

    d. Conformance monitoring service: a service that provides real-time monitoring and alerting of imminent 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 efficiency of the planned flight. This service would include the arrangement, negotiation and prioritization of operational volumes, routes or trajectories while the UA is airborne.

- Discovery service: a service that provides users of the UTM system with information on relevant services available for a specific geographical volume of airspace (e.g. provision of meteorological information).

- 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).

- 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.

- 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.

- 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.

- 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.

- 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.

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 occur in all classes of airspace, and will include transit across the boundary between controlled and uncontrolled 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. A significant amount of UAS operations are expected 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;
- 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.

The likely increase in operations in the low-level environment and above populated areas raises questions about the sustainability and scalability of a UTM system and the ability of ATM infrastructure to accommodate these new users;

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. Resolving this gap may require modification of current classes of airspace or potentially the creation of new classes of airspace.
- *Airspace access.* Policies, rules and priorities must be developed to support equitable access to airspace. Rules of the Air.
- The Rules of the Air specifying flight rules, right-of-way, altitude above people and obstructions, and distance from obstacles 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 have not been determined.
- *Certification/approval standards.* Certification/approval standards are needed for the UTM system, particularly when interacting with an ATM system. Additionally standards are required for the UA, which need to address the principles of airworthiness, but 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*. Procedures are needed that dynamically address contingencies both of the UTM system(s) and of the aircraft operating within the UTM system.

Issues

The applicability of requirements for airspace and procedure design has yet to be considered. When doing so, topics such as navigation performance should be included.

To ensure system reliability and safety, frequency spectrum availability and supportability need to be determined.

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 to the remote pilot/operator complemented by tools and procedures to effectively address scalability. Separation provision 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;
- 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;
- 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; and
- 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

UTM as a concept or capability is still under development. ICAO is continuing its efforts as a global aviation forum to support States, industry and academic and aviation professionals, by exploring solutions for UTM and developing the UTM framework and core principles.

This framework is not intended to endorse or propose any specific UTM system design or technical solutions. Its aim is to provide an overarching framework for such a system. The intent is for this to be a living document and as more information is gained, the UTM framework will be updated.

Continued participation from industry is necessary to explore safety standards for product development, and to allow global interoperability.

The appendices contain information gathered from the submissions to ICAO's 2017, 2018, 2019 and 2021 request for information (RFI) and from material provided during the respective DRONE ENABLE Symposia. To ensure the information in the UTM Framework remains relevant and current, as part of the drafting of Edition 4, the original first five appendices were reviewed and updates provided where appropriate. This updating effort also resulted in the consolidation of what were previously Appendices D and E into a single Appendix D.

APPENDIX A

REGISTRATION, IDENTIFICATION AND TRACKING

Presentation Review (from DRONE ENABLE 1 (2017))

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 allow the CAA of the State in which the operation is occurring to identify the nationality of the aircraft, the operator and what person 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

Proposals for registration systems 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)

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. It was recommended that a minimum international standard should be introduced. 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 conventional 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. operations of RPA for which broadcasting their identification and position would not be appropriate due to security related issues).

Summary and Updates since DRONE ENABLE 1 (2017)

UAS registration, identification and tracking initiatives to support the UTM ecosystem are being progressed and implemented worldwide, including:

- Regulation and policy maturation concerning UAS registration and identification
- Technology advances that support regulation and policy guidance
- Standards creation to support the UTM ecosystem

Regulations and Policy

Regulation and policy development are often viewed as long-term activities that have significant process restraints. Nevertheless, progress has been noted in several States advancing and publishing policy guidance on registration and identification. A list of UAS related regulations and policy can be found at the ICAO UAS Toolkit (https://www.icao.int/safety/UA/UASToolkit). These policies include exemptions to smaller UAS under a specific weight or purpose of flight (hobby/recreational). Additionally, a significant amount of demonstration flights to support the development of regulation/policy for tracking and identification are also occurring worldwide.

Technological Advances

Significant technological advances have occurred in digital information exchange, mobile applications that interface between operators and UAS Service Suppliers, and information hosting. Additionally, live and simulated demonstration tests have occurred that explore implementation and sharing of preflight and inflight operational intent, airspace access approval, on- or near-airport operations, weather information exchange, and situational awareness of other UAS operations. The expectation is that technological advances will continue, supporting the maturation of the UTM ecosystem. Below are a few examples:

- Low Altitude Authorization and Notification Capability (LAANC) – https://www.faa.gov/uas/programs_partnerships/data_exchange/
- Guardian UTM - https://www.altitudeangel.com/solutions/guardianutm-os/
- DJI Geospatial Environment Online (GEO) - https://www.dji.com/flysafe/geo-map

Standards Creation

Robust standards development is occurring worldwide to support the UTM ecosystem. Organizations such as ASTM, the European Organisation for Civil Aviation Equipment (EUROCAE), and the International Organization for Standards (ISO) have published UTM supporting standards with a significant amount of additional work is still in progress. Examples of published standards that support the UTM ecosystem include:

- ASTM International - ASTM F3411-22a Standard Specification For Remote ID And Tracking;
- EUROCAE - ED-270 – minimum operational performance specification for Unmanned Aircraft Systems (UAS) geo-caging; and
- ISO/TR 23629-1:2020 - UAS traffic management (UTM) — Part 1: Survey results on UTM.

Continued maturation and implementation of registration, identification, and tracking of UAS are still needed by States and industry in order to achieve an integrated and harmonized UTM framework and operating environment.

APPENDIX B

COMMUNICATIONS SYSTEMS TO SUPPORT UTM INTEGRATION

Presentation Review (from DRONE ENABLE 1 (2017))

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 framework must be established to ensure that information systems are safe, secure, reliable, and interoperable, and that they 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 UAS communications protocols generally should be taken into consideration, including, as applicable, those for:

- communications link between UA control stations and UA, including for aircraft command and control (C2 Link);
- 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 or remote pilot stations/UA control stations and the respective UTM and ATM systems.

Communications systems specifically in support of UTM will need to account for the following paths:

- between UAS operators and UTM (e.g., remote identification information; traffic awareness; no-fly zone warnings);
- between UAS pilots and UTM;
- between UTM and UTM;
- between UTM and supplementary data providers (e.g., data supporting flight planning decisions, such as quality of the connectivity throughout the planned flight; traffic density information).

Communications Solutions

There are a variety of possible technological solutions capable of supporting a framework for UTM communications systems. Different concepts of UTM communications service provision through entities such as ANSPs, governmental organizations, and private third-party suppliers will evolve, similar to those currently utilized for ATM systems. Such entities may play a key role in centralizing UTM communications between UAS and other 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 implementation of UTM, it is envisaged that a data exchange mechanism to fulfil the set of communications paths identified above will rely upon this variety of communications technologies. There are already various technologies available that permit the exchange of data between two or more aircraft that can also be used for communications within a UTM architecture.

Such communication solutions can be roughly divided in two main areas related to the range of the communication type: short-range or long-range. Short-range technologies use super-high frequency (SHF) for example Bluetooth and Wi-Fi, whereas ultra-high frequency (UHF) for example cellular data, and, for even greater distance, satellite.

These communications solutions will support the overall objective of aircraft communications with and within the UTM system to fulfill information exchange across the various paths that have been identified above. These technologies have different performance characteristics, topologies, and business models; accordingly, their appropriateness for communications systems that support UTM integration will likely vary based on local conditions.

Spectrum Requirements

Traditionally, specific (and limited) frequency bands have been identified and allocated for aeronautical use. Such allocations are the result of years of negotiation and coordination undertaken at the International Telecommunication Union (ITU). Radiofrequency spectrum currently available for dedicated aeronautical operations represents a scarce resource. In this context, the ITU has played a decisive role in allocating protected spectrum to UAS operations considered necessary for safety-critical functions (C2 Link for remotely piloted aircraft systems (RPAS), for example).

As UTM systems are further developed and deployed with their unique communications requirements for smaller UAS, which may or may not require aviation protected spectrum, it will be imperative to identify other means for communicating essential data in a UTM environment. New communications solutions have presented themselves, as noted above. There are also new spectrum bands being made available to enable those solutions, especially with the worldwide implementation of Fifth Generation (5G) architectures.

A variety of spectrum resources in the terrestrial-based domain, as opposed to spaced-based domains, are being evaluated and deployed for the provision of the type of communications services outlined above. These resources include discussions related to deployment of 5G communications architectures.

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

In addition, some unmanned flight missions can utilize unlicensed spectrum resources for local operations, especially at lower altitude. As discussed in more detail below, cellular carriers are also exploring methods of leveraging their spectrum holdings to provide an alternative to spectrum allocations that have been made for UAS operations.

In all of these cases, standards for the application layers of the communications systems will need to support the communications requirements inherent in a UTM system – and, likely, between UTM and ATM environments. These standards must address the relevant safety implications owing to link-loss events, as well as metrics pertaining to the latency, integrity, availability and redundancy of data transmission that support all features of the UTM. ICAO has initiated the work of creating these standards, as have other organizations.

Concerns regarding frequency availability, licensing, and spectrum 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 and the local State Communications Regulator.

Cybersecurity

Cybersecurity risks and vulnerabilities must be taken into consideration. A robust security framework must be established to address potentially malicious attacks to UTM communications systems and functions, 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 committing to a 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), or a combination of terrestrial and satellite-based communications were mentioned. For any of these technologies to be selected, issues regarding suitability for urban or rural areas, sufficient availability of bandwidth or capacity, spectrum availability, or resilience from the effects of interference will need to be addressed. State Communications Regulators must also add these considerations into any planning process for defining UTM-UAS communications methods, technology, and licensing.

LTE already provides capabilities for supporting most of the use cases for UTM-UAS communications. It is expected that, for reasons of bandwidth and the development of the next generation communications architectures, only the most stringent UTM link requirements will need to wait for widespread 5G deployment. For communication between UA and UA control stations, cellular networks provide a variety of quality of service levels that can meet differing performance requirements in terms of priority, latency, and error rate, offering additional flexibility for different paths within the UTM communications system.

With the advancement and further deployment of 5G, cellular networks will posses several new features that might improve capacity, latency, reliability, and security (e.g., network slicing, multi-access edge computing, eMMB). The global standardization of cellular networks is increasingly supporting multiple industries; as to aviation, the 3GPP has started already to include requirements for supporting the needs of UA up to a certain altitude. For UTM operations, cellular networks could offer both pre-flight and in-flight functionality. As an example of pre-flight information, cellular networks could provide crowd heat maps that help asses the risk of the proposed operation. Cellular networks also already have location services that provide the position information of the device; this service could be beneficial for the UA remote pilot or UA operator to verify the UA position and increase the authenticity of the information provided to the UTM.

APPENDIX C

GEOFENCING-LIKE SYSTEMS

Introduction

Geofencing-like systems were discussed at the DRONE ENABLE 1 Conference, and this Appendix originally presented the output from those presentations and discussions. However, the state-of-the-art in geofencing has evolved very considerably since then, so it has been decided to build on that earlier material in order to bring the Appendix up to date.

Presentation Review (from DRONE ENABLE 1 (2017))

States may wish to restrict the operation of UA in certain areas, often for safety, security or sensitivity reasons, and this can be implemented by geofencing. Information on such areas may be published by States or ANSPs in aeronautical publications and possibly in a manner not currently used by aviation.

A geofencing function includes an airborne piece of equipment (hardware or software, or both), supported by a ground service. A geofencing/geoawareness system, and its associated service, 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.

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

- *Static*: data provided relies on published, stable data (e.g. aeronautical information publication (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).

Some considerations on geofencing/geoawareness functions or services include:

- *Data integrity;*
- *Accuracy of the UA position;*
- *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;*
- *Enabling authorised access to geofenced zones;*
- *Contingencies;*
- *Remote pilot knowledge;*
- *Enforcement;*
- *Procedures and regulations for establishing geofences; and*
- *Safety nets for recreational users.*

As currently exists for manned aviation, a set of standards and processes for airspace restrictions should be developed. In addition, the following aspects would need harmonization:

- *Processes and procedures 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.); and*
- *UA actions under contingency operations (lost C2 Link, fly-aways, emergencies, etc.) and system responses.*

Operational Need

Competent authorities often need to designate portions of airspace that have some restrictions or privileges for all or some UAS operations in order to address and manage issues pertaining to safety, privacy, protection of personal data, security or the environment, arising from UAS operations. Such a portion of airspace is referred to as a UAS Geozone (UAS Geographical Zone). Such zones can be used for geofencing purposes by equipping UAS with suitable Geofencing Systems.

Geozones may be designed to prevent entry by UAS into the geozone (also known as geo-exclusion, in which case the geozone is also a 'No fly Zone' (NFZ)), or to ensure that a UAS remains within a geozone (also known as geo-caging). Geozones do not necessarily apply to all UAS, and their applicability should be included in the geozone definition. Care must be taken when designing the lateral bounds of geozones to ensure that they do not create safety risks or excessive disruption to the population below by, for example, creating UAS 'hot-spots' as UAS avoid proximate geozones.

The vertical extent of geozones may be defined purely for an airspace managed by UTM, or could extend into other classes of airspace, as shown in the figure below:

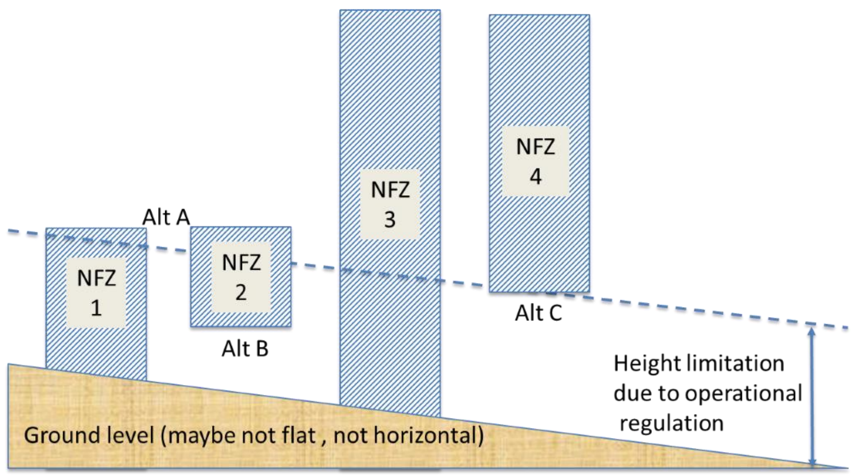

Figure C- 1

As with the issues that need to be addressed regarding common altitude, navigation and temporal references for manned and unmanned Operations the vertical extent of the geozone must be published with no ambiguity as to the 'altitude' reference, and the programming of the geofencing system must respect the same reference. Moreover, the regulations and procedures should define how the UA's geofencing system should behave in each circumstance.

A geofence is defined by geographical coordinates and a time slot (4D definition), for example:

- A circle of radius 2NM centred on 50.9439N, 6.9627E
- Upper limit: 2000ft (AMSL)
- Lower limit: SFC
- Permanent

In addition, its operational function (NFZ, geocage) and applicability must be clearly stated.

The definition of geozones should be published in information sources that are designed for UAS operators, and, where appropriate, in conventional aeronautical publications, to ensure awareness among all interested airspace users and ATM/UTM agencies. Information exchange between UTM and ATM is covered in Appendix D.

Geofencing

Geofencing is a UAS function based on the data provided by authoritative sources on UAS geographical zones, which detects a potential breach of airspace restrictions and assists the remote pilot in preventing that breach. Implementation of such geofencing systems need to be standardized to ensure consistent responses to the geofence data. A geofencing system has two sub-functions:

- Geoawareness is the minimum sub-function of geofencing that provides a warning alert to the remote pilot to avoid breaching an airspace restriction, the remote pilot being then responsible to act on the UAS controls to adapt the trajectory with regard to the airspace restrictions.

- Automatic geofencing is an additional optional sub-function that automatically prevents the UA to penetrate a forbidden zone by connecting with the flight command and control system and engaging an adequate manoeuvre without any remote pilot action.

The geofencing function (either geoawareness or automatic geofencing) can be defined for any mode of UA command and control:

- Manual control: direct control of aerodynamic surfaces & engines by the remote pilot (even in manual control, the automatic geofencing will block the UA at the external limit of the forbidden zone)

- Semi-automatic control: speed vector control by the remote pilot; e.g.: heading + horizontal speed + vertical speed; and

- Automatic flight: automatic following of a succession of legs between waypoints previously defined by the remote pilot (even in automatic flight, the geoawareness alert will be raised to the remote pilot who will react and take manual control if no automatic geofencing is implemented).

UTM Geofencing Services

The geofencing capability on board UAS can be supported by services provided by a UTM service provider. Since it is intended that UTM will allow for multiple service providers to operate in the same volumes of airspace, any geofencing services must be harmonized to prevent any variances in data that may lead to safety or other issues.

Geofence data can also be used by UTM service providers to help with monitoring the conformance of UAS with their planned trajectories. However, this forms part of the UTM monitoring service, and not the UTM geofencing service.

UTM geofencing services can be supplied at different levels of complexity, depending on the operational environment and the systems available. For example:

- Pre-tactical geofencing provides an up-to-date restricted area database before a flight that allows UAS operators to perform mission planning that avoids known NFZs and respects geocages. This does not necessarily require an in-flight data connection between UA and service provider, since the service is provided before departure.

- Tactical geofencing provides geozone information to the ground-station during the flight so that the operator can instruct the UA to avoid the new geozone. This implies a data connection between the service provider and the UAS operator at all times, though not necessarily directly to the UA.

- Dynamic geofencing allows new geozone information to be uplinked to the UA during flight, which implies a data connection between the service provider and the UA. In addition, in order to provide a dynamic geofencing service, the service provider must have continually-updated access to geofence data that meets all the requirements for timeliness and data quality.

Provision of these services requires the service provider to meet the regulatory requirements for being a service provider as well as the performance requirements for service provision, system performance and for protection of data integrity.

Standardization and Regulation

For geofencing capabilities and services to be effective in supporting the safe and expeditious operation of UAS, it is essential that the key elements are standardised, and such standards should be underpinned by Regulation. To promote interoperability, it is advisable that such standardization and Regulation be harmonised at a global level, as described in the presentation summary above.

Of particular importance are the performance requirements for air and ground systems, as well as for the service provision and the maintenance of data integrity.

With so many new service providers entering the domain, many of whom may not have been familiar with aeronautical update cycles, such as aeronautical information regulation and control (AIRAC), the possibility arises that software updates to the many inter-connected systems may happen in an uncoordinated manner, leading to unforeseen incompatibilities. Standardization should also address this to ensure that service providers and their suppliers are aware of the need to remain coordinated to safeguard interoperability and performance requirements.

APPENDIX D

UTM-ATM BOUNDARIES AND TRANSITION

Introduction

The second DRONE ENABLE Symposium (2018) sought to address some of the UTM implementation issues as they relate to the safe integration of UTM operations in the airspace. The problem statement as included in the RFI was:

> *As the development of UTM moves forward, there needs to be a focus on the next evolution of the ability for aircraft (both manned and unmanned) to safely and efficiently transition between any future UTM system and the concurrent ATM systems. The primary requirement is to ensure safe integration, without negatively impacting manned aviation and the safety of persons and property on the ground, considering security and equal accessibility for all airspace users.*
>
> *Understanding the boundaries and the transition phases of these systems, how they interact and how best to exchange essential information will enable States, regulators and industry to continue to advance this global industry while preserving safety of all airspace users.*

The RFI asked that submissions propose "*practical solutions for describing the ATM/UTM boundaries, transition between the boundaries, what constitutes "essential information" and the capabilities needed by each system to allow for secure and efficient operations.*"

Although UTM and ATM have the same objectives (i.e., to prevent collisions and enable safe and efficient operations) there are significant differences in the ways UTM and ATM may achieve this end. It is, important for States to consider the configuration of airspace in which aircraft may be transitioning between UTM and ATM. As the concepts mature and airspace management between UTM and ATM gets more integrated, the notion of a boundary between UTM and ATM is expected to eventually disappear. Throughout the initial and maturation phases of the UTM environment, identification and exchange of essential information between UTM and ATM will be required.

Presentation Review (from DRONE ENABLE 2 (2018))

<u>*Boundaries and Transitions*</u>

Several DRONE ENABLE 2 (2018) 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 standards making organizations. 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, is managed, with different levels of services, by the established ANSPs. ANSPs provide these services based on Annex 11 — *Air Traffic Services,* and *Procedures for Air Navigation Services — Air Traffic Management* (Doc 4444) as well as regional/national regulations. Flight information service (FIS) is provided either by a flight information centre or by an air traffic control unit and includes information that is intended to enhance safety.

Aviation, including ATM, has a long history during which a high level of safety has been developed and is maintained. A notable characteristic of ATM is that it functions with a well-established and proven safety management system. ATM has become complex enough to make quick development and implementation difficult. By contrast, UTM is innovative and fast developing, but its level of safety and robustness has not been defined and validated. Integration of UTM and ATM will be driven by the business needs and necessity.

The establishment of boundaries between UTM and ATM 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 (2018) presenters noted that interoperability is a key requirement for UTM-ATM interface.

Several DRONE ENABLE 2 (2018) presenters also outlined the gaps between responsibilities of UTM and ATM. The gap has materialized from the fact that the process for designation of UTM service suppliers, their certification, and how they should demonstrate a minimum level of safety and quality of service has not been defined. On the other hand, established ANSPs are regulated and follow well established procedures.

In addition to the gaps which are complicating the establishment of UTM-ATM boundaries, it is hard to develop UTM in isolation from the existing ATM systems and 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. 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. Consequently, presenters expressed the view that UTM services may, in fact, be shared between UTM and ATM.

Several of the presentations at DRONE ENABLE 2 (2018), addressed UA capabilities for operating in all types of airspace and at all altitudes/levels. Discussion topics included scenarios when 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.

Essential Information Exchange between UTM and ATM Systems

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.

Considerations

Boundaries Between UTM and ATM

This appendix addresses practical issues and future implementation considerations of a UTM operational architecture in airspace where existing ATM services are provided for volumes of airspace within a State's jurisdiction. 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" regarding 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 or operational 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. Additionally, the boundary between UTM and ATM can also be seen as different flight rules or altitude reference system usage.

At the outset, the exercise of addressing UTM-ATM boundaries focuses on UTM 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 air 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 States to identify where operational, airspace, and technology elements might require additional planning (e.g., appropriate rules, policies, and procedures) for the integration of manned and unmanned 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. In the long-term, UTM-ATM integration would provide a common system able to support different operations. It is also expected that a reference system for the vertical position of aircraft, common to UTM and ATM systems, will be necessary to provide appropriate vertical separation.

Transitions Between UTM and ATM

As industry needs and technology evolve, it is easy to imagine unmanned operations sharing airspace with conventional aviation. Research, demonstrations, and ad hoc individual approvals for operations such as those near airports are already underway. As these efforts mature, the desire for unmanned operations to be able to transition between UTM and ATM will increase. Enabling operations requiring transitions between boundaries will require a careful analysis of existing policies, procedures, and information exchange for both UTM and ATM operations.

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 UTM and ATM providers. UTM and ATM information must be accessible to relevant stakeholders (airspace users, service providers, States, etc.). Architecture may permit coincident UTM and ATM operations, but at a minimum, the exchange of essential information at the boundary must be ensured for safe and efficient operations. Appendix E illustrates further considerations on interoperability.

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.

Key considerations in designing UTM-ATM boundaries include:

- UTM operations may require new ways of managing airspace categories and volumes, based on future concepts, which may affect the interactions between UTM and ATM.

- Performance capabilities of UA and their operator or remote pilots (e.g., aircraft characteristics of speed, size and maneuverability) should be considered when designing the size and shape of UTM - ATM boundaries.

- The airspace design should account for type and performance characteristics of the UA and other aircraft operating in or adjacent to the volume of airspace.

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) do not sufficiently accommodate UAS operations. Any changes to the flight rules will need to be consistent and complementary to the ones defined for manned aviation. Studies are underway to provide new or adapted flight rules that States will need to consider and apply at the boundaries between UTM and ATM.

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

- identification of roles and responsibilities of UTM and ATM systems in terms of level of service provided and service responsibility should the two overlap;

- development of operational procedures and coordination processes:

    - for transitioning between UTM and ATM;
    - to allow traffic under UTM control to operate in an ATM environment and vice-versa; and

  - for operations in close proximity to adjacent airspaces;

- establishing separation standards between UA and between manned aircraft and UA; and
- 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 may not accommodate UAS operations as envisioned under UTM given the highly automated nature of UTM operations. Analysis 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 processes/requirements.

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

Technology Considerations

States should consider 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).

Essential Information for UTM/ATM Interoperability

Operations between UTM and ATM boundaries will require information exchange to be complete and seamless. To this end 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; and
- current aviation connections, through SWIM, will need to be extended to new airspace users, who will also need to use information services and data exchange models.

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

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

Elements of Information Exchange

Service Provider considerations

- Management of aeronautical data and information

The aeronautical data and aeronautical information to be exchanged between UTM and ATM systems will include, inter alia, the airspace data and information. Airspace is usually defined and classified by States, with boundaries relating to geographical coordinates and vertical limits; it can either be permanent or temporary.

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

The entity responsible to originate aeronautical data should be clearly identified. Aeronautical data may be originated by more than one organization or authority.

All data should meet a minimum set of standards for data quality, be delivered in the time frames required, and be validated/certified. States should consider putting in place procedures and policies to verify and validate aeronautical data for compliance with data quality requirements. In addition, the system requirements for authenticating the information source will need to be established.

The exchange of aeronautical data and information may happen either in advance or in real-time. Service providers will make available changes in aeronautical data or new aeronautical data to all UTM and ATM participants under a regulated system (e.g. AIRAC) or through NOTAMs or eventually by SWIM information services providing access to airspace information and updates.

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

When aeronautical data and information is exchanged and used, the format and scale used will need to be defined to ensure it is fit for purpose taking into consideration system and user needs.

- 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 for transitioning aircraft between the two systems. These processes and data would also enable strategic de-confliction of aircraft between UTM and ATM.

- Tactical coordination and de-confliction

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

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

- Qualification of service providers

As States establish and expand UTM services, qualification of service providers should be defined. Qualification processes can support the stratification of services to be provided (i.e. required, recommended, or optional services) as well as define the processes for qualifying each service.

Considerations for Information Exchange between Systems

UTM and ATM information exchange considerations that States may need to address when approving a UTM system to interact with an ATM system include:

- 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.

Examples of Information Exchanges between UTM and ATM

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 such as regulatory enforcement. The types of data that may need to be exchanged include, inter alia:

Aircraft Information

- aircraft identification and registration information (some of this information may be regulated by the State)
  - Electronic identification,
  - Operator contact information,
  - Remote pilot contact information,
  - State of Registry and State of Operator,
  - Aircraft type,
  - Aircraft category (e.g. aircraft, rotorcraft, glider, vertical take-off and landing (VTOL), hang-glider),
  - Wake turbulence considerations,
  - Aircraft surveillance capability (e.g. ADS-B, Mode A/C or S);
- UA performance capabilities (e.g. minimum or maximum speed, climb rates, max. altitude);
- UA method of control (e.g. RPAS, automated, or other);
- 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);
- DAA capability (e.g. ACAS);
- ATC communication link type (e.g. VHF, telephone, data link); and
- information to facilitate charging of service fees - this may originate through the ID and registration or other source.

Operation Information

- UA position – 4D geospatial information to required standard;
- flight plan, including flight notification;
- mission type(e.g. cargo, passenger);
- 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;
- C2 Link state - quality and status of C2 Link (e.g. Lost C2 link, partial loss);
- airspace access and authorizations;
- 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); and
- ATC communication link status;
  - Priority status (e.g. aircraft in distress, medical).

Other Information that may be shared

Other information may be collected regarding conditions within the airspace which are impacting availablity of 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). 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.

Summary and Updates since DRONE ENABLE 2 (2018)

This appendix has discussed issues related to UTM-ATM boundary definitions, transitions between UTM and ATM, and some elements of information exchange in support of integration of UTM and ATM. It is recommended that States take a phased approach to integration of 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. Considerations for integration of unmanned and manned operations include:

- limitations in how airspace is managed between UTM and ATM drive the need to address how the two management approaches can be integrated.
- testing will likely need to be implemented in a phased approach; and
- airspace users and UTM/ATM personnel will need to understand the operational requirements of both systems.

As the desire to perform increasingly complex unmanned operations near or in ATM airspace increases, States will need to consider the issues addressed here in a manner that allows for eventual erasure of the boundaries between UTM and ATM.

APPENDIX E

UTM SERVICE PROVIDERS (USP) ORGANIZATIONAL CONSTRUCT AND APPROVAL PROCESSES

Presentation Review (from DRONE ENABLE 3 (2019))

Presentations demonstrated that States do not share a common vision of how to organize and manage UTM Service Providers (USP), or if/how to enable multiple USPs to operate together in the same airspace. All agreed that CAAs would 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.

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 governance structure will be, the list of elements cannot be exhaustive.

Recognizing the possible 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 provides more detail for the different architectural options, linking the differences to the concepts raised in the first section.

- The third and final section looks into the future, suggesting how initial implementations should evolve.

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.

<u>Criticality of Services</u>

Operational experience from both UTM and ATM shows that some services are more critical than others. For example, safety-critical services will be more important than some supplemental services.It was widely agreed that critial services would need a greater degree of oversight and that such services may need to be provided by the State, a trusted source and/or a single service provider. 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 the State, a trusted source and/or a single service provider, if any. UTM services could 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 UTM service provision to be effective.

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.

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 effective cooperation with manned aviation. 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 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 of a process for approving and monitoring a USP.

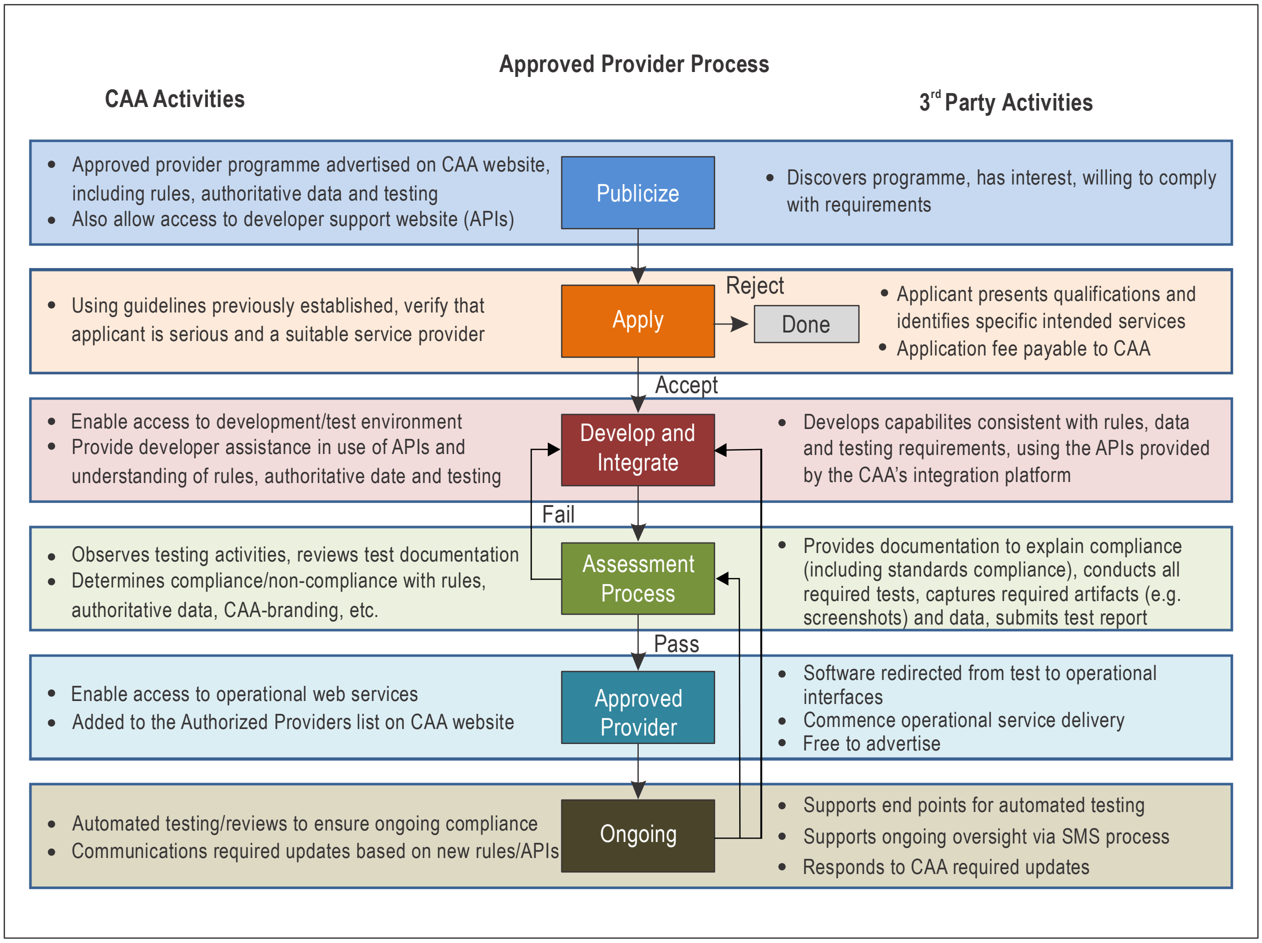

Figure E-2 – Approved Provider Process

The needs of the military and security communities must be taken into consideration, by both regulator and service provider. This should include mechanisms for determining and applying prioritization of operations, 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.

Interoperability

As far as possible, implementation of UTM should be based on standards produced and agreed by international standards making organizations. 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 prescriptive standards.

The key mechanism for ensuring interoperability between USPs is through effective data exchange. USPs will process a range of data from many different sources, and the quality requirement for each type of data should be specified and standardized. Considerations for data exchange between UTM and ATM can be found in Appendix D, and many of these apply equally to exchange between USPs, including the adoption of SWIM principles and data exchange models (AIXM, FIXM and IWXXM). 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 suplimental data services providers (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.

Centralized Service Provision

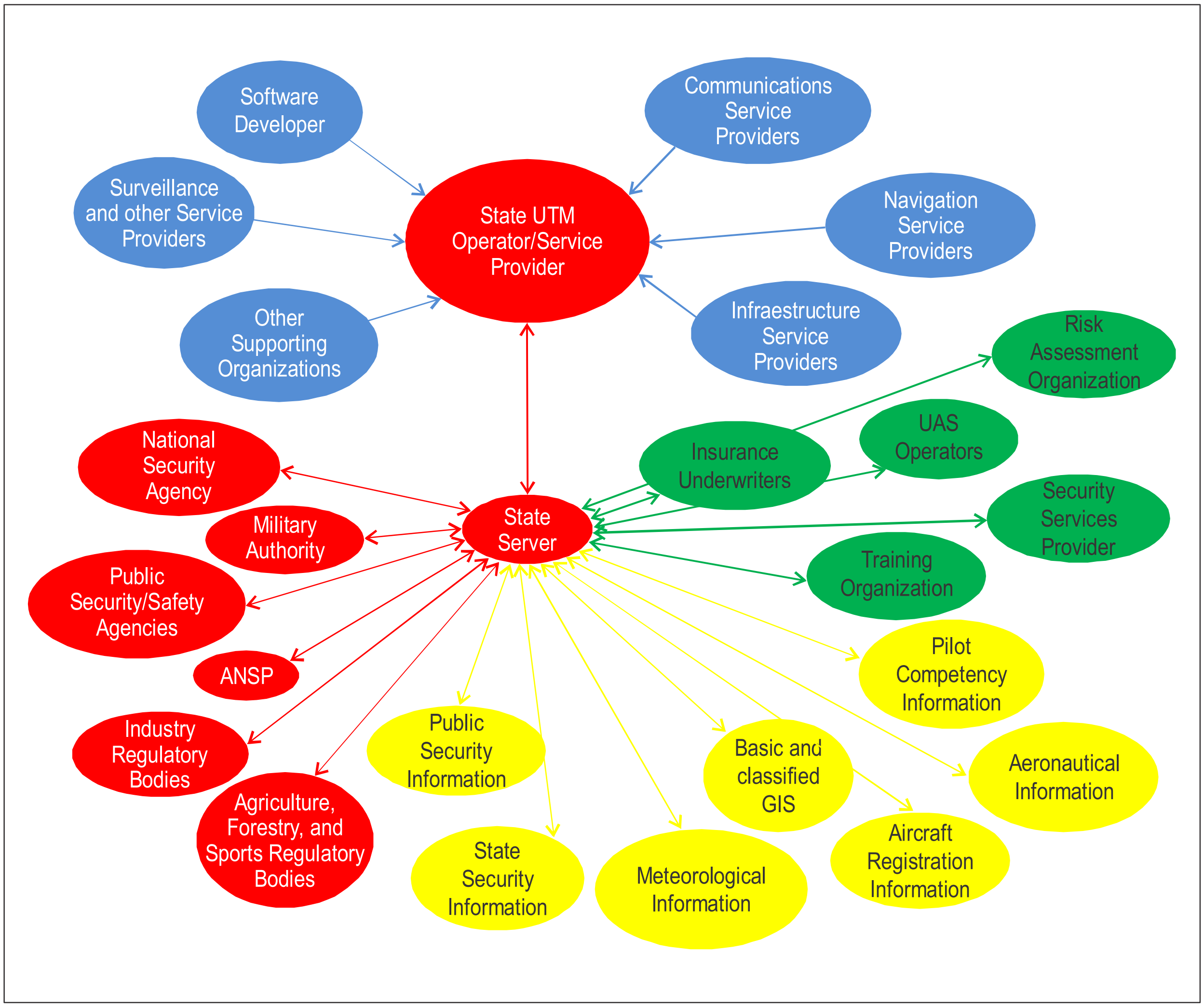

Figure E-2 – Centralized Service Provision Architecture

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.

Federated Service Provision

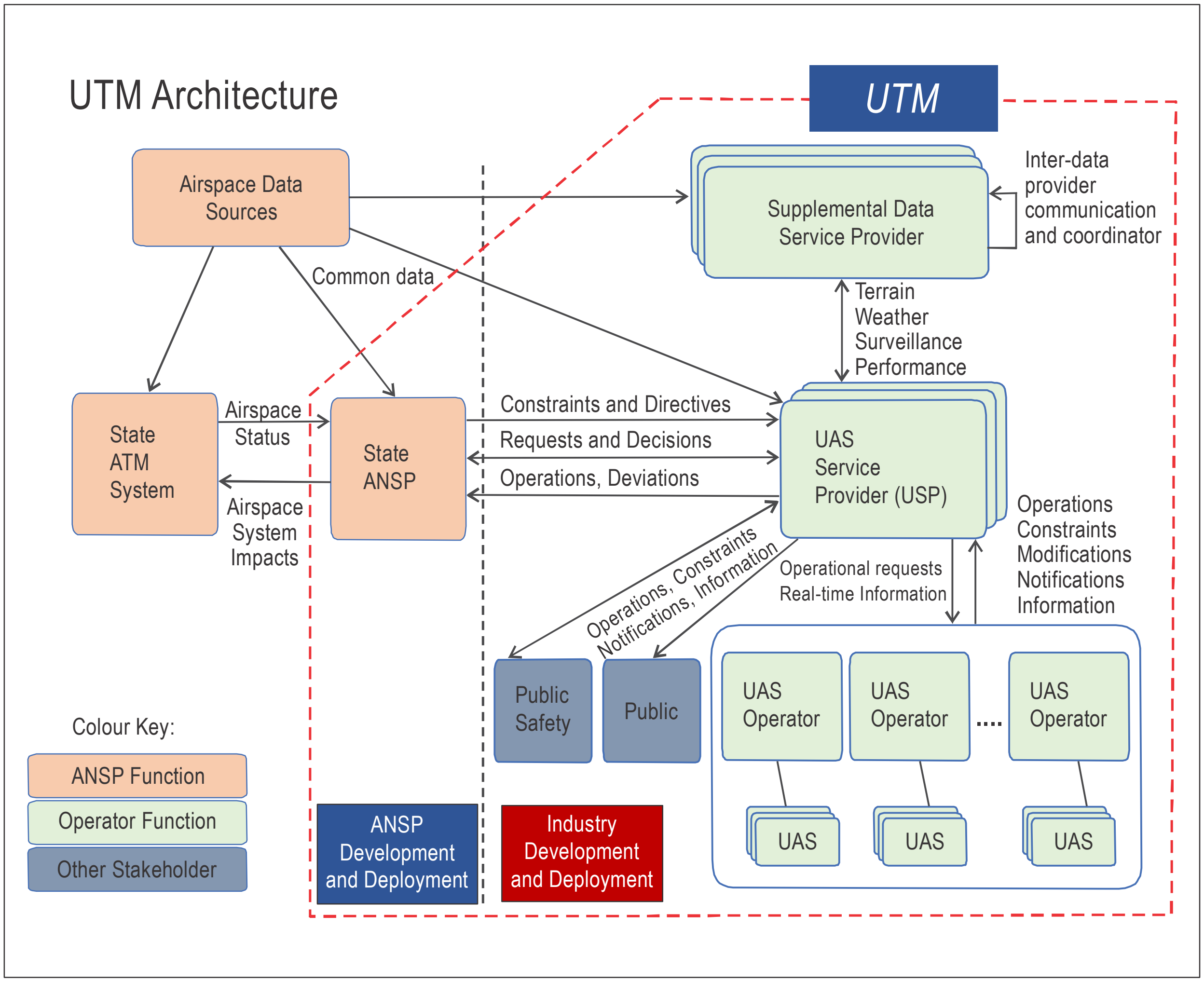

Figure E-3 – Federated Service Provision Architecture

In this example of a federated architecture, there is still one 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 different 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

Future evolution is set to be rapid, and will follow paths as yet undefined. Supporting this continued evolution while encouraging innovation 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 allowing performance and risk-based standards to be used, whenever possible, as the mechanism for defining how UTM is implemented.

- Increase in efficiency in UTM service provision, especially as numbers of UA increase. This increase in efficiency 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, ANSPs and 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.

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.

APPENDIX F

DECONFLICTION AND SEPARATION MANAGEMENT

Presentation Review (from DRONE ENABLE 3 (2019))

A key element of any safe separation provision in a UTM system 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, 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.

The *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 factors 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 UTM and ATM requirements, or unmanned aircraft to satisfy manned aviation airspace requirements. With appropriately defined UTM-ATM boundaries and integration, it is anticipated that manned aviation equipage requirements for ATM will 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. Figure F-1 summarizes the differences between reactive and proactive deconflcition services.

	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

Figure F-1 – Reactive vs Proactive Deconfliction

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 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?

APPENDIX G

UTM SAFETY RISK ASSESSMENT AND CONTINGENCY PLANNING

Presentation Review (from DRONE ENABLE 3 (2019))

DRONE ENABLE 3 (2019) participants provided information on various safety 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 safety risk assessment methods, best practices or recommendations.

Several presentations introduced different safety risk assessment methodologies available, focusing on various types of safety 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 UA-centric. Other presentations highlighted the need for more encompassing risk assessment methods including other traffic or the environment.

Some 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 need for 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 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 analyzing 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 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 and 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 are assessed, 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 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 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 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. UTM and ATM 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 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[2] , CORUS MEDUSA[3] , 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*. 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.

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

APPENDIX H

UNMANNED AIRCRAFT PERFORMANCE REQUIREMENTS IN A UTM ENVIRONMENT

Presentation Review (from DRONE ENABLE 4 (2021))

The presentations during the RFI session at DRONE ENABLE 4 (2021) were principally focused on Communication, Navigation and Surveillance performance requirements and were mainly based on three principles:

1. *A risk-based approach is crucial to ensure that diverse operations remain within acceptable risks levels to other airspace users.*

2. *The focus should be on the key critical components within the UAS and use cases that determine the UA performance requirements in a UTM environment.*

3. *There is a need for minimum UA performance requirements to ensure the UA complies with the flight plan defined in the UTM system and to provide assurance that the UA operates along the intended trajectory within a suitable level of tolerance for the applicable UTM airspace.*

Introduction

There are many different types of UAS operations which will be conducted in the same volume of airspace with other manned and unmanned aircraft. Therefore, UTM will support a diversity of UA with different performance characteristics.

UA operations need to be managed in a safe and efficient manner; this appendix describes the UA performance requirements in a UTM environment and builds upon elements presented at DRONE ENABLE 4 (2021). It should be noted that there were certain elements in the presentations requiring a higher level of maturity and/or further research and testing.

Considerations

Many types of UA are expected to be managed by a UTM system and such a system will need to support diverse UA performance characteristics in shared airspace. At the same time, there is a need to further develop and validate UTM systems to support UAS operations in both simple and complex environments (taking into account ground and air risk) while considering UTM traffic density (e.g. urban operations, mixed traffic). Additionally, the following aspects must be considered:

- UTM related legal aspects resulting from how regulators define a framework of UTM operations;

- close cooperation between UA manufacturers, industry, and governments to standardize the UA performance characteristics, to develop a comprehensive UAS performance requirements framework which is harmonized with the technical requirements of the UTM environment;

- flexible approach for balancing UA and UTM performance requirements, operations performance, and integration requirements, necessary to accommodate expected near term growth of UAS operations; and

- evolving technology and innovation that will enable UA to improve their performance characteristics in varying environmental conditions.

High-Level Principles for UAS Performance Requirements

The type of UAS operations and the environment (e.g. traffic density or population density on the ground) will affect the requirements that the UAS will need to fulfil, in order to mitigate the associated risk and ensure a given level of safety.

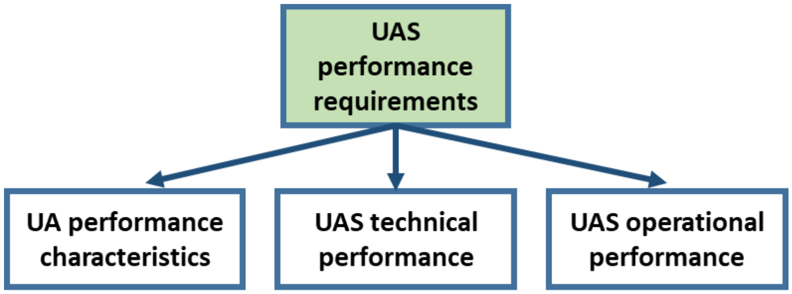

Figure H-3 - The three core UAS performance requirements principles

UA Performance Characteristics

UA operating in any type of UTM environment will need to comply with relevant performance requirements. Nevertheless, given the large variety of UA, a wide range of performance characteristics will need to be identified for locating the UA, confirming its trajectory and maintaining safe separation in a UTM environment. These characteristics may include:

- airspeed;
- altitude;
- latency in
  - the execution of control inputs; and
  - communications with UTM;
- manoeuvre performance, including climb and descent performance;
- navigation precision; and
- onboard collision avoidance.

The UA performance alone may not, in and of itself, mitigate the associated air and ground risk associated with the UAS operations. Since UA performance cannot be considered in isolation, there is a need to have technologies and methodologies in place to support the needed interface between UAS and UTM systems.

UAS Technical Performance

Communication, Navigation and Surveillance (CNS) infrastructure is an essential enabler for the provision of services to new entrants (e.g. UTM services). However, there is a wide range of airspace users with different operational, technical and business needs using common CNS services and infrastructure. A significant challenge remains in that some CNS infrastructure are not sufficiently spectrum-efficient, and may not be sufficiently protected from security threats. These issues will have to be addressed to ensure safe and efficient operations.

- Communication

Communications for UAS should support internal UAS functions (i.e., between the UA and remote pilot station) and communications between the UAS and external components or airspace users (i.e. between the UA and UTM).

Communications internal to the UAS
The performance of the C2 Link in segments of flight where the operation is not automated is a fundamental part of the overall performance of the UAS needed to meet the safety objectives of the airspace.

ICAO identifies the following performance parameters for the C2 Link, which may also apply to UAS operating in a UTM environment:

- availability: the probability that an information exchange between the control station and UA can be initiated when required;

- continuity: the minimum proportion of information exchanges to be completed within the specified transaction expiration time (TET), given that the service was available at the start of the transaction;
- latency: the maximum time permitted for an information exchange to pass one way through the C2 Link;
- transaction expiration time (TET): the maximum time for the completion of an information exchange after which the safe operation of the RPAS may be compromised; and
- integrity: the probability that an information exchange is completed with no “undetected errors”.

UTM Related Communications External to the UAS

These communications requirements are currently not specified, nor fully identified, but include:

- communications identified as basic mandatory services or risk assessment related mitigations between the USP and the UAS; and
- communications between generic CNS service providers (such as GNSS, or ADS-B) and the UAS. These services already have service performance specifications. The interface specifications, such as antenna performance, as an example, help in understanding the final performance available for the UAS.

● Navigation

Navigation performance is also a direct performance factor for the Network Identification service.

Performance-based Navigation (PBN)

Applying the PBN framework, the UA navigation performance requirements could be quantified using the following metrics or key measures:

- accuracy – the difference between the estimated position and the real position of the aircraft;
- integrity – the system’s ability to provide warning in time when the system is not safe for use; and
- continuity – the probability that the system will function as it should for the duration of the flight operation.

Required Navigation Performance (RNP)

Navigation system error and flight technical error are the main contributors to the RNP metric. RNP levels in different environments (value affected by population, mission type, airspace performance, airspace restrictions etc.) will provide meaningful data. However, this could require a framework to be able to evaluate RNP for use in a UTM environment. Such a framework would consider:

- airspace design;
- UA and its navigation capability;
- need of a safety factor - RNP; and
- relevant RNP standards.

● Surveillance

Surveillance for a UA relates to the ability to provide information to a ground system that is used to separate traffic in real time. The positional information can be generated by the UA (e.g. ADS-B) or by external systems (e.g. radar or wide area multilateration (WAM)).

The scope of surveillance in a UTM environment may be different from the scope of surveillance in an ATM environment. For example, the logic of deconfliction and automatic responses to conflict alerts may be specific to UTM airspace. In addition, the mixed nature of the traffic involved also requires functions (e.g. tracking, air monitoring) that may not currently be understood as “surveillance”.

The nature of the UTM environment and the versatility of the UAS design and control modes enable many direct and indirect methods for accurately determining and reporting the position of a UA.

In this context, additional work is required, including clarification of the applicable flight rules in the UTM environment, before attempting to define and specify surveillance performance requirements.

Specifications for the supported UTM and ATM services and use cases will drive the surveillance system requirements.

The following are typical surveillance systems metrics for consideration in each UA-UTM use case:

- minimum data items;
- update interval;
- probability of update (of required data items);
- accuracy of required data items (e.g. position, speed etc.);
- timing quality;
- integrity;
- availability; and
- continuity.

In addition to the CNS issues listed above, the following technical performance aspects should be considered:

- detect and avoid (airborne-based and ground-based traffic in all types of weather);
- C2 Link requirements commensurate with concept of operations (CONOPs); and
- UAS cyber resilience requirements (addressing C2 Link, remote pilot station, and UA).

UAS Operational Performance

In addition to the technical elements mentioned above, several other factors could address or shape the UA performance requirements, including:

- applicable flight rules and operational procedures;
- UAS CONOPs;
- UAS safety performance case justification for CONOPs (e.g., MEDUSA, SORA, NASA, IASMS);
- UAS safety management system (USMS)[4] [5];
- UA responses to detect and avoid warnings;
- requirements for contingency and emergency procedures;
- degraded performance limitations (i.e. those resulting from minimum equipment list (MEL), or configuration deviation list (CDL));
- UAS environmental/weather limitations;
- capabilities and limitations of the unmanned aircraft;
- application of Human Performance limitations commensurate with CONOPs and UAS; and
- prioritization categories based on the performance and operational approval of UAS.

High-Level Principles for UTM Performance Requirements

UTM-related projects are emerging in many countries in order to accelerate the access of UAS to the airspace. Because there are different types of UA, UAS and UAS operations, the mitigation of associated risks will likely require airspace modifications, different operating rules, software, information management for flight planning, flight awareness in the area the UA are flying, etc. Therefore, it is essential to recognize the UTM performance requirements and key principles

[4] UAS safety management system includes all elements of ICAO Annex 19 (*Safety Management*) and ICAO Doc 9859 (*Safety Management Manual*).
[5] Operations of UAS in the U-space and UTM may require an SMS that integrates with the In-time Aviation SMS (IASMS) architecture proposed by NASA. https://arc.aiaa.org/doi/10.2514/6.2021-1978

for a UTM system in order to determine not only the key minimum UA performances required for a safe environment but also to consider other elements in the UTM ecosystem that are complementary to UA safety performance and to ensure that UA operations meet target levels of safety.

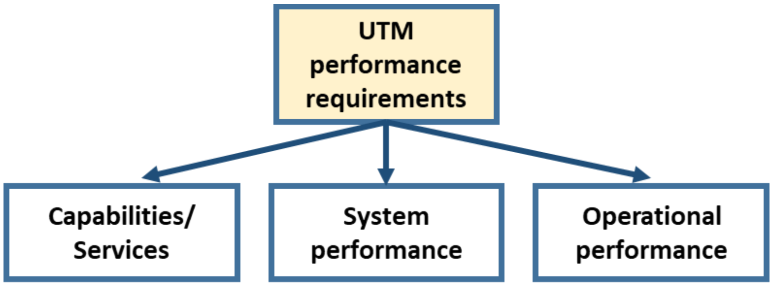

Figure H-4 - UTM performance requirements principles

<u>UTM Capabilities from the Standpoint of the UA Performance and the UTM Services</u>

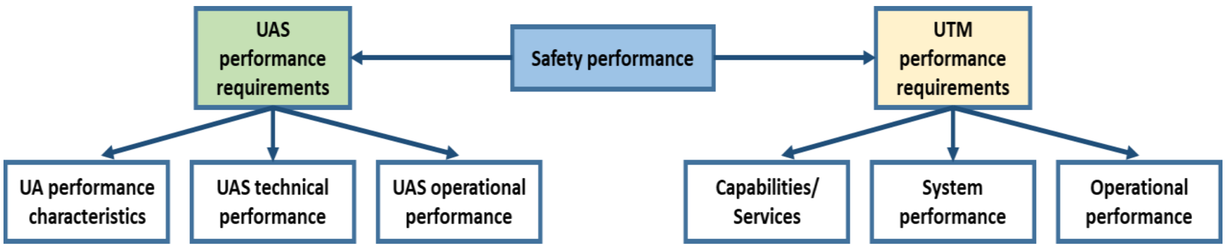

Figure H-5 - UTM system operational overview

The level of safety in a UTM environment is built upon a combination of the performance of the UAS, the performance of the UTM services and the performance of the interaction between the UA and the UTM services.

Overall performance requirements need to be defined for each type of operation taking into account the airspace characteristics. Where UTM is provided, the UAS operator needs to assess which part of the performance requirements is addressed by the different UTM services. This will then allow the operator to understand what performance requirements are expected from the UAS.

Consequently, before defining the UA performance requirements, it must be understood how the overall UTM system operates in controlled and uncontrolled airspace.

The performance and behaviour of the UTM capabilities, services and enablers are important factors in defining the UA performance requirements needed to operate in a given UTM environment. Examples of these UTM capabilities, services and enablers might include:

- data management (e.g. geo-fencing protection of airspace zones);
- development of communications requirements;
- frequency spectrum availability;
- provision of airspace rules and tailored aeronautical information in support of UTM conflict detection;
- the expected UTM performance for specific UTM services to help define the UA performance requirements;

- regulations and standards for allowing UA to operate in the UTM airspace. Define what type of UTM services should be standardized. (e.g. rules of the air, right-of-way to resolve conflicts, and protocols, which should be made available to the UAS/operator);

- identification of the UTM stakeholders and setting up of procedures for collaborative participation; and

- definition of UTM services performance requirements taking into account ground and air risk, airspace, geographic area and the availability of infrastructure to support the UTM services and thus the UAS operation.

Other Areas for Consideration

Consideration should be given to the link between UA performance and UTM requirements based on a volume of airspace within which a UTM service is provided. Areas for consideration may include:

- a flexible UTM CONOPs leading into the development of airspace volumes, spacing (separation minima) and conflict resolution;

- procedures, rules, and guidance for: (a) pre-planning, (b) communicating, and, (c) coordinating UTM operations with ANSPs for short notice requests, routine scheduling and demand/capacity balancing;

- planning and coordination for strategic and tactical traffic flow as well as separation for cooperative and non-cooperative traffic;

- information sharing protocols and rules between UAS, ANSPs, and operators for emergency and abnormal situations;

- automation performance matrix since automation performance and capabilities may differ between UA even within type, depending upon UAS control station and software combinations;

- an impact assessment taking into account the type of operation, flight conditions, airspace classification and impact on ATM[6];

- assessment of UA performance environmental impact (e.g., noise, battery charging, flight volumes, and times of operations);[7]

- UA operating limitations in certain airspace or areas (e.g. noise and speed restriction thresholds for operations in urban corridors, or near vertiports, aerodromes, or urban launch and recovery areas); and

- list of UTM services required for those volumes[8] .

Conclusions and Recommendations

UA performance requirements and UTM services must support target levels of safety for UAS operations in the UTM environment.

The lack of standards for UA performance requirements and objectives hinders the establishment of precise UA performance requirements needed in a UTM environment.

The regulatory framework for UAS operations in a UTM environment is still evolving, challenging development of UTM-related standards.

Some standards addressing UAS performance have been developed by standards making organizations, but more are necessary. Additional standards are necessary to support safe operations within a UTM environment, such as a common altitude reference system and detect and avoid systems.

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[6] For example: EUROCONTROL Final Report of Riga Airspace Assessment.

[7] European Aviation Safety Agency (2021) study on societal acceptance of urban air mobility in Europe. https://www.easa.europa.eu/sites/default/files/dfu/uam-full-report.pdf

[8] Reference material – CORUS project. The CONOPs elaborates the U-space services UTM in Europe and proposes how they could be used in combination to achieve safety, public acceptance and efficient operation.

Therefore, demonstrations and research (use cases) continue to be a critical element for providing key information to regulatory authorities and standards making organizations as efforts to integrate a UTM system into the airspace continue.

In this respect, States should set up a stepped approach to evaluate UA performance through:

- research findings and analysis between the UA performance and the different functionalities;
- modeling of test cases for both UA and UTM performances;
- UAS risk management (SORA and other alternative means of compliance (AMC));
- establishment of performance-based rules for UTM service providers, including a validation process for UAS operations;
- identification of sources of authoritative data for UTM services, as it is essential that UAS operations and UTM systems use common data; and
- development of the standards needed for the different functional allocations of UAS in a UTM environment.

APPENDIX I

CERTIFICATION OF UAS TRAFFIC MANAGEMENT (UTM) SYSTEMS

Presentation Review (from DRONE ENABLE 4 (2021))

The UTM system certification requirements session included presentations covering diverse aspects of UTM system certification. Presentations covered high-level topics such as common terminology, organizations which might certify UTM systems, and conditions for when certification might be required. Other presentations provided more detailed analyses of system design and evolution, the use of simulations to assess safety during certification, and the relationship between risk and the need to certify systems. These topics, and others, are covered in more detail in the following sections.

Introduction

Given the nature of expected initial UTM capabilities, UTM systems may have to demonstrate and achieve a level of reliability normally found in certified aviation systems. However, traditional aviation standards may be excessive or unnecessary for the intended function of UTM and could have a negative impact on innovation and implementation of UTM concepts.

Considerations

There are many considerations that should be taken into account when determining whether a UTM system will require certification or approval and, if so, what approach would be most appropriate. It is important to note that consensus on terminology has yet to be achieved. Terms such as “approved”, “authorized”, “permitted”, and “certified”, are often used interchangeably. For the purposes of this appendix, the terms “certification” and “certified” are intended to indicate that a regulatory body (CAA generally) has approved the use of a system for a given purpose, in accordance with applicable regulations.

The following list of considerations is not exhaustive, but rather should be considered as a minimum list of considerations when determining the certification approach to use:

1. Does the system provide services that are mandatory for participation in UTM?
2. What risk is associated with use of, or failure of, the system?
3. What are the system interfaces and are any of the interfaces with ATM systems?
4. What safety data is available and can simulations be performed to provide additional data?
5. How will system updates be addressed?
6. How will the system interact or negotiate appropriately with UTM services from other providers?

Answers to the above questions will help determine the requirements and processes for certification. Some systems may be certified by self-declaration; for example, a system providing an optional service that does not interface with any safety critical systems. On the opposite side of the spectrum, a safety critical system providing <u>required</u> services for UTM participation might need certification by the regulator. A hybrid approach whereby a regulator could delegate certification to an outside body is also possible. Examples are given in Figure I-1

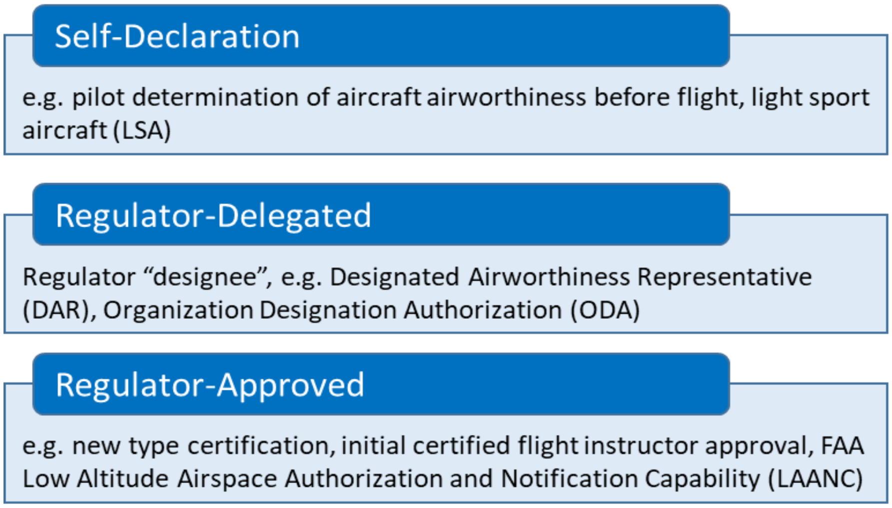

Figure I-6 - Certification Approach Examples

As UTM matures, standards making organizations will likely address system certification with the expectation that a combination of performance-based and prescriptive standards will result from these efforts. Performance-based standards will provide system designers and developers more flexibility in how they meet regulations, facilitating the use of new technologies as they become available. As technology matures, standards may need to be updated to allow use of the new technology. Prescriptive standards may be more appropriate for some initial UTM systems as well as for use by States with limited resources which are certifying only basic UTM systems.

No one-size-fits-all certification solution is expected to emerge as UTM systems mature. States are likely to use a combination of approaches to certify systems. The combination of approaches used will depend on safety and risk factors, in a particular implementation of UTM to include local and statewide considerations.

<u>Certification Elements</u>

To ensure the safety of UTM operations, several certification elements will likely be specified and monitored by the regulator. Specifications for security, availability, and latency will be required to keep shared data secure and accessible as needed for planning and operation of UA. Security planning will need to address the means for determining who is authorized to access data, authentication of authorized users, and data integrity. Early planning for system availability will address how the system will scale with increased traffic density while still meeting a target reliability. Finally, system design will need to consider data centre location and mitigation strategies to address system latency.

As the number of operations in an airspace increase, it will be increasingly difficult to address security, availability, and latency as a fix or patch to an existing system. It is possible and preferable to consider these issues proactively in architecture definition. To address some of these issues, cloud-based approaches to UTM system architecture may be considered. A cloud-based architecture might allow for a fully auditable system and would include plans for mitigation of security events. This structure would assume that faults will happen and include alarms for when metrics are not met as a part of the system architecture. Redundancy and partitioning could mitigate latency concerns.

However, regulators should consider the challenges of certifying cloud-based systems, especially those provided on an as-a-service or subscription basis. Such a system may not reside within the State itself, and the inner workings of the system may not be readily accessible to the regulating authority.

This may make traditional ATM approaches to safety assurance difficult to implement for UTM, especially when considering safety critical functions. Thus, approaches for UTM certification may also need to consider alternative approaches, which must nonetheless be appropriate for the level of risk that the system brings to the overall aviation system. Some considerations include:

1. recognition of (or credit for) certifications in another State;

2. joint certification activities with another regulator, or group of regulators;

3. provision of SLA targets and ongoing performance data from the service provider to the regulator;

4. impact mitigation techniques used elsewhere in the information technology industry, such as sandboxes, soft launch, beta testing and proving periods;

5. simulation;

6. credit for in-service safety performance at a lower safety assurance level; and

7. ongoing robustness, regression and penetration testing of the system to ensure ongoing compliance and acceptability.

Certification Strategy

If a UTM application forms part of a larger suite of applications (e.g. registration, airspace authorization, etc.), it is recommended to develop an overall strategy for certification with the approval authority for the UTM suite. For example, a Remote ID application may not be safety-critical, in itself. However, it may become safety critical if a DAA application is intended to later rely upon it as an input. An application designed for UAS package delivery may require a higher safety assurance level at an early stage if later it is intended to support higher risk operations.

It should be noted that a UTM application designed to an existing ATM system standard, such as DO-278/ED-109A, or, an emerging standard within the UTM community will greatly assist a certifying authority (i.e. CAA) in achieving a suitable level of safety assurance. The next section further explores emerging standards in UTM.

Standards Development

Simulation

Simulations can be used as a tool to ensure that systems function safely and as expected. They offer several advantages in validation, verification, and safety assurance. Simulations bring speed and ease of data collection; more simulated operations can be flown in a given time period than live flight operations. Simulations also enable fast stress testing of the systems used in UTM as well as concept exploration without the risk involved in live flight operations.

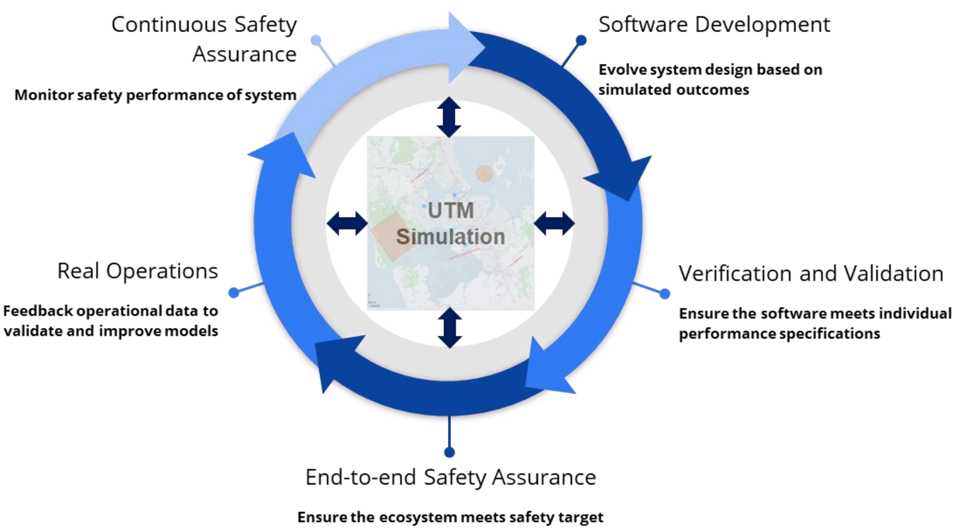

Figure I-2 - Use of Simulation

Results from simulations can be useful in multiple ways. Standards making organizations can include guidance on the types of simulation data that can be used in support of system certification as well as when simulation data can be accepted in place of actual flight data.

Simulation data can also be used to ensure safety during system updates and evolution. This will support use of automated oversight mechanisms for rapid changes without compromising safety as part of the continuous delivery concept used by many software companies. Continuous delivery is a set of procedures for testing, staging, and deploying code quickly, sometimes several times a day. It is a key driver for innovation as it gives companies room to try new approaches without negatively impacting the system. Use of simulation data in support of a continuous delivery mode of software development may allow for an oversight mechanism that actively supports innovation in a new way.

In-time System-wide Safety Assurance (ISSA)

Certification of UTM systems will rely on safety-focused architectures that ensure such issues as system errors, unit conversions, and regular updates to systems can be addressed quickly and thoroughly. Conventional aviation relies on the manual SMS process that will not scale to the number of systems and pace of change in UTM systems. A potential replacement for the SMS is In-time System-Wide Safety Assurance (ISSA)[9].

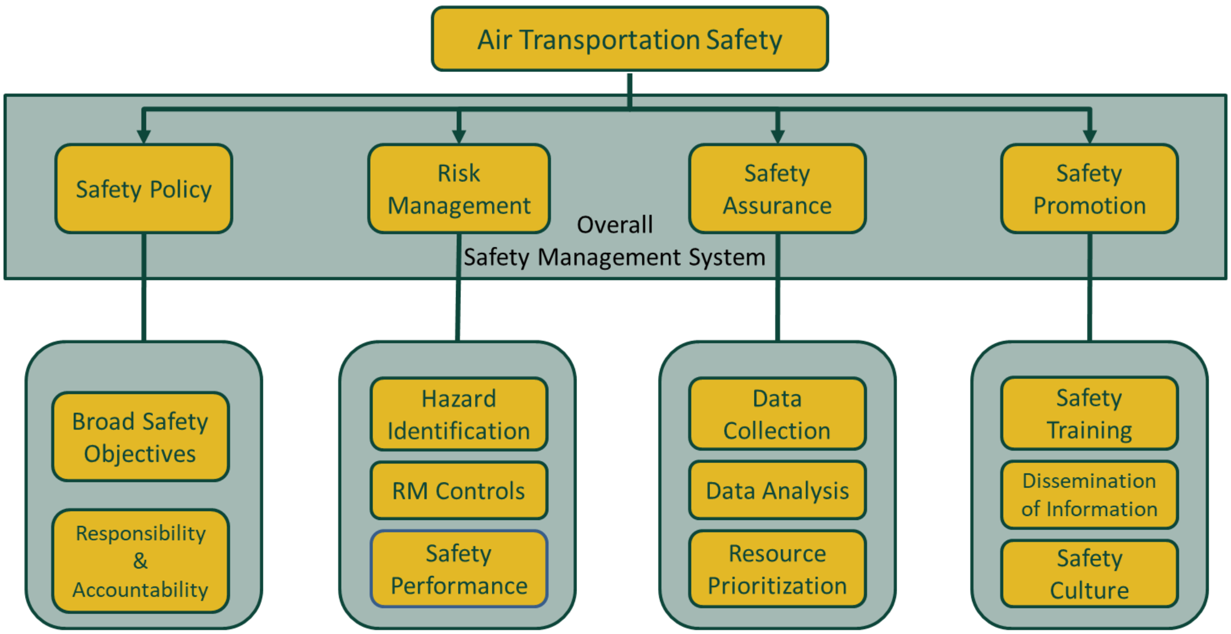

Figure I-3 - Traditional Safety Management

[9] https://nari.arc.nasa.gov/sites/default/files/attachments/ISSA.Conops.Final_.20.07.01.pdf

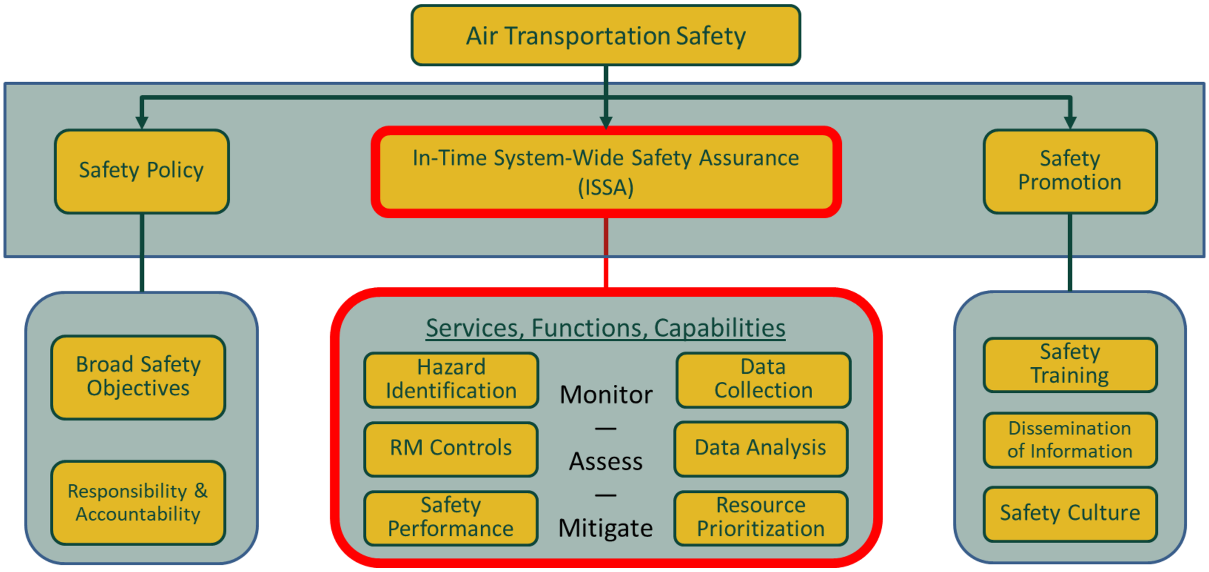

Figure I-4 - In-Time System-Wide Safety Assurance

ISSA replaces time-consuming manual steps with automated functions meant to monitor systems, assess issues, and mitigate risk. Monitoring can be passive (recording and watching the overall health of a system via metrics analysis) or active (looking at and analyzing the data going into, coming out of, and being used in a system). Identification of issues early facilitates quick assessment of issues and impacts. Mitigation can include standard design patterns already in use in UTM (e.g. communication of warnings with operators during emergency operations). This approach to safety management may help scale safety processes to suit the complexity of the UTM environment.

Oversight

The oversight approaches a State uses to certify UTM systems will likely be influenced by the number and specific types of UTM systems in a State's UTM ecosystem. As the number of systems increases, it is less likely that an oversight approach relying solely on approval from the regulator will work due to resources and staffing concerns. It is likely that a State might start with an oversight approach solely relying on approval from the regulator and gradually incorporate other mechanisms of regulatory approval as the UTM ecosystem matures. Ultimately, the oversight structure will evolve based on an assessment of the safety impacts of system certification.

In addition to the certification mechanisms mentioned in the section above, a new model for oversight, using a delegated industry body, could also be considered, where appropriate. This model relies on an independent group with the authority to approve certification for UTM systems. This oversight body could be an international non-profit organization funded by industry through a dues schema. On the surface, this structure may seem similar to the regulator delegated oversight structure. However, by ensuring that the technical staff are only working for this delegated industry body, any potential for conflict of interest (perceived or real) is minimized. An advantage of this structure is its dedication to the technical aspects of certification, ensuring that these activities will be the sole priority of the organization.

Practical Example

Switzerland's Federal Office of Civil Aviation (FOCA) voluntary network-based Remote Identification (RID) implementation provides a practical example of how a UTM system can be implemented with the appropriate regulatory oversight. In this case, RID was implemented through a public private partnership and relies on three pillars: a master agreement, a data exchange mechanism, and access authorization. The master agreement describes the rights and obligations of the parties involved and primarily addresses risk assessment and mitigation. It is important to note that FOCA only plays a regulatory role in these agreements. Data is exchanged using a platform called InterUSS and allows parties to exchange data required to use the RID service. FOCA is responsible for the authorization server, has control over who has access to the data and can intervene as required.

In setting up this system, initial onboarding, testing, and auditing was primarily a manual process involving phone calls and on-demand testing. As the system matured, it has become more automated allowing on-demand testing and fewer manual processes. In conclusion, as UTM systems mature, manual processes used during initial rollout phases that cannot scale as participants increase should be replaced with automated processes and procedures.

APPENDIX J

UTM INTEGRATION INTO AERODROMES

Introduction

Unmanned aircraft may operate to, from, or in the vicinity of aerodromes and blend with conventional aircraft operations. These operations may take place at controlled or uncontrolled aerodromes, including heliports, and may take place both on the airside and landside. It is essential that the issues, challenges and risks of UTM and ATM interaction within the aerodrome environment are clearly understood and addressed, enabling industry to progress toward full integration. With an increased need for aerodrome connectivity to address new entrants, it is important to identify and understand the roles of various stakeholders in the entire ecosystem.

UAS operations are increasing in many sectors, including at aerodromes, with limited rules and processes in place. UAS operations will need to have limited impact on ATC as it may be difficult to effectively manage the many different types of aircraft and operations particularly as the number of UAS operations increase. Of particular concern will be the fact that UAS will have very different performance characteristics and procedures compared to conventional aviation.

Building on materials presented at the DRONE ENABLE 4 (2021) Symposium this appendix describes the context around UTM integration into the aerodrome environment.

UTM will be a key enabler for allowing UAS operations at aerodromes, noting that the required technology and standards to support UTM services will enhance safety of UAS operations. Furthermore, the high levels of digitalization and automation functions on which UTM relies will facilitate additional services to be provided to the ATM system, enhancing integration and safety for all operations conducted at the aerodrome.

Overall, the aim of UTM services at aerodromes is to improve situational awareness and safety levels while integrating all airspace users.

Main Outputs (from DRONE ENABLE 4 (2021)

Stakeholders

The integration of UTM in the aerodrome environment potentially generates new interactions with a multitude of new stakeholders. The interactions between these stakeholders need to be adequately established and governed, as they will involve the timely distribution of essential information amongst the relevant stakeholders, existing and new.

Typical stakeholders are:

- Airside:
    - i. air traffic control;
    - ii. UTM service provider;
    - iii. ANSP of the relevant airspace(s);
    - iv. remote pilots;
    - v. pilots of conventional aircraft;
    - vi. airfield emergency services;
    - vii. CNS service providers and engineers; and
    - viii. airfield operations (e.g. ground handling, wildlife management, security, etc.).

- Landside:
    - i. airlines and other conventional aircraft operators;
    - ii. UAS (fleet) operators;
    - iii. flight planning and meteorology;
    - iv. apron managers; and
    - v. support service providers.

- Supporting:
    i. airport operator/owner;
    ii. aviation regulators;
    iii. external emergency services;
    iv. environmental agencies;
    v. law enforcement agencies;
    vi. counter-UAS services;
    vii. UAS manufacturers; and
    viii. general public.

Notwithstanding some commonalities, each aerodrome is unique, with its specific layout, stakeholders, infrastructure and operations. To identify the complete list of stakeholders involved in the operations, and their roles and responsibilities, an assessment of airspace, aerodrome perimeter and the surrounding area is required. In this context, it is equally important to clarify stakeholders' roles and responsibilities. For example, to address the subdivision of responsibilities related to the prioritization of the different types of air traffic.

It was noted that there is a need to ensure engagement with the aerodrome community, both inside and outside the aerodrome boundary, to provide adequate understanding of the new operations taking place on, above and around the aerodrome.

UAS Operations at Aerodromes

Aerodromes are one of the most complex environments where UAS operations can take place due to their different features and specificities. To integrate manned and unmanned operations, it is essential to have a system where every stakeholder involved can trust the actions of others. As such, it is essential to establish requirements, limitations and certifications to create the necessary level of trust. Establishment of procedures to manage such operations is essential, in particular, for conventional air traffic and ATC.

Key integration requirements that UAS operations should consider include, inter alia:

- avoid negative impacts to existing, controlled or uncontrolled, aerodrome operations;
- comply with the regulations and procedures (existing and future);
- avoid compromising existing aviation safety levels or increasing of risk; and
- avoid negative environmental impacts.

UAS applications at aerodromes could include:

- Airside:
    i. airfield/runway inspection;
    ii. NAVAID calibration;
    iii. obstacle evaluation;
    iv. aircraft inspection;
    v. apron management;
    vi. wildlife control and monitoring; and
    vii. perimeter security.
- Landside:
    i. building/roof inspection;
    ii. infrastructure inspection;
    iii. ground vehicle traffic management; and
    iv. cargo delivery.

- Nearby:
    i. approved UA transit;
    ii. unknown UA operations; and
    iii. counter-UAS.

UAS operations are not limited to the aerodrome boundary. Another business case is the concept of shuttle services between city centres and aerodromes.

UTM Services at Aerodromes

Whether or not UTM services are necessary at an aerodrome, any UAS operations will need to be managed safely and effectively. ATC at the airfield will remain the sole authority for operations in the airspace and on the manoeuvring area and all UAS activities will need to be appropriately coordinated with ATC. However this may not mean that ATC will be actively 'controlling' the UA. ATC could instead manage UAS operations though local procedures and airspace definitions (e.g. 'UAS operation Type B approved in Block 12A, max height 100 ft. AGL, 12:00 to 12:20Z', etc.). As long as the UA is managed in accordance with the local procedures, there may be no need for instructions or clearance to be provided by ATC. That being said, ATC may have to be directly involved in specific cases, such as, but not limited to, crossing a runway, inspection in the approach path, runway inspections, etc. Finally, there would need to be contingency procedures and alerts for abnormal events, however this would not necessarily need to be a UTM service.

If UTM services are required at an aerodrome, the process for deployment of a UTM system will need to identify which services, roles and responsibilities are necessary for UAS operations in controlled and uncontrolled airspace. The establishment of UTM services should facilitate a cooperative interaction between UAS operators/remote pilots, and the key stakeholders involved in the integration of UAS. These services will enhance the interoperability between UTM and ATM services as well as the coordination between the ANSP and USPs. An initial set of minimum UTM services would likely be required to enable UAS operations at aerodromes. A UTM system supporting a specific aerodrome may also need to interface with UTM systems in surrounding airspace. This would support UA arrivals and departures at the aerodrome and could also provide valuable data for counter-UAS activities in the case of unauthorized UA operations.

The UTM services envisioned to be essential for UAS operations at aerodromes are:

- UAS operator and remote pilot registration within the local UTM system;
- UA registration;
- geo-awareness;
- flight planning and authorization;
- traffic information;
- network identification;
- strategic de-confliction;
- real-time tracking and monitoring;
- tactical conflict detection; and
- interface with ATM (where applicable).

It is expected that the integration of a UTM system into the aerodrome operational environment would go through several phases ranging from:[10]

- Segregation: where traffic types are fully segregated to ensure safety. Operations would normally affect ATC, but the characteristics of the requested location do not require direct interaction with ATC and ATC can work independently around the UAS operation. UAS operations that are planned over a movement area, such as runway or approach/departure path of a controlled aerodrome would need to be "shielded" from other aircraft.

- Accommodation and coordination: where the traffic types operate in coordination within the same environment. Coordinated operations refer to UAS operations where interaction with ATC is required, as determined through assessment of the characteristics of the location and equipment levels and capability of the UAS. To mitigate the risks to an acceptable level, these operations will need an appropriate risk assessment and may need to have a standard 'UA buffer' applied in order to provide sufficient distance between the UA and all other aircraft, manned or unmanned.

- Integration: where all traffic types operate seamlessly together. This phase would support operations in which the equipment requirements, capabilities and reliability of the UAS meet similar safety objectives as conventional aircraft, and the operations can be largely managed through systems and processes. This final stage will be the most challenging one to achieve and will need significant efforts in terms of system integration between UTM and ATM systems.

Key Considerations

When planning the deployment of a UTM system at an aerodrome, as either an operational trial or a live implementation, the following key considerations will require careful assessment.

Current State of Affairs

A number of States have already implemented UAS operations at aerodromes, mostly on a research and development or demonstration basis. Despite a positive business case, the expansion of UTM implementations is currently limited by the lack of adequate procedures, regulations, standards and operational experience. As experience is gained, UTM services will mature and expand, facilitating greater coordination among UAS operators, aerodrome operators and ATC. The close proximity of manned and unmanned aircraft will continue to pose safety barriers to deployments until such systems are in place.

Operational Aspects

In the majority of the current implementations, UTM is considered as a separate system from ATM. The future framework aims to achieve full and seamless interoperability across UTM and ATM systems. Current UAS operations at controlled aerodromes may pose a significant impact on operational efficiency and, due in part to limited automation, results in challenges on human resource and aerodrome capacity limitations. In order to further implement UTM and adequately manage the available capacity at aerodromes, interoperability between UTM and ATM systems is necessary, with automatic sharing of critical data, managed with limited human interaction. Expectations are for air traffic control officers (ATCOs) to only interact with the UTM system to manage exceptions, rather than all operations. In addition, due to the sensitive nature of the operations and complexity of the operating environment, special requirements such as minimum training, qualifications and licensing of remote pilots would be required. Similarly, ATCOs will need to be adequately trained on the UTM system, UAS operations and local procedures.

Another operational aspect that requires further consideration is the management of emergencies that may occur with manned and unmanned aircraft and the contingency planning required in order to ensure safe operations.

Eventually, consideration should be given to integrating UTM into the airport collaborative decision-making (A-CDM), where implemented.

[10] Drones in the airport environment: Concept of operations & industry guidance, ACI-Europe, 2020

Technical Aspects

Operations in and near aerodromes require communications capabilities, between all participants involved, that are precise, reliable and timely. A possible approach is digitalization of the communications system using data link communication. This approach will save time, ensure that messages are delivered and read, and reduce the potential for human error. The interface with ATM should provide a complete situational awareness for the ATCOs. To the extent possible, the interface design should integrate with existing systems and human machine interfaces to avoid the need for additional equipment.

It is equally important to ensure the availability of a trust framework within which different stakeholders can operate. This framework has to include trusted users and systems, which will come through data trust. Within the UTM system, users and equipment need to be registered and recognized. There is also a need for the system users to gain trust in the degree of automation being employed, particularly as the UTM system moves towards the concept of management by exception.

Regulatory and Standardization Framework

The current implementations of UTM at aerodromes have primarily been accomplished outside of a harmonized global regulatory framework. However, to ensure the safe and orderly deployment of these operations, local level regulations and processes have been established. These local regulatory frameworks, which have been developed with inputs from all affected stakeholders, allow for a fully integrated approach to managing the movement of all aircraft. This is particularly necessary to address issues of responsibility, scope and in some cases operational or technical roles or interfaces.

As a step forward towards establishment of a framework, creation of best practices and sharing of experience will be extremely beneficial. Development of guidance material for a safe, efficient and effective use of UTM at aerodromes would also be beneficial.

Additional Considerations

The aerodrome environment is complex, both operationally and from an infrastructure perspective. The integration of UAS into the current operational landscape will create new challenges that will have to be addressed. Other potential items for consideration when operating UAS or establishing a UTM operating environment near or at an aerodrome are:

- contingency management;
- spectrum and frequency management and/or segregation;
- aerodrome emergency planning, in particular UAS incident or accident response; and
- local community and media engagement.

In any case, the integration of UAS or the establishment of a UTM operating environment at an aerodrome will need to undergo appropriate safety risk management processes and evaluations to ensure the implementation meets expected levels of safety for the operation and that all interfaces are adequately identified and evaluated.

There are several reference materials available to guide further UAS integration into aerodrome environments, such as *ACI Europe Drones in the airport environment: Concept of Operations & Industry Guidance.*

Conclusions

On a global scale, there is a clear interest in the deployment of UAS operations at and near aerodromes. Stakeholders may use UAS to bring efficiency, reduce workload, and improve safety and economic value of their operations. UAS deployments will accelerate over the next few years and will need to be adequately managed through coordination and the involvement of, and coordination between, all stakeholders and affected parties.

UTM has shown its potential in supporting UAS operations at aerodromes and assisting ATM stakeholders in their roles. The key aim of UTM services at aerodromes is to improve situational awareness and safety levels.

Defining the interfaces, the operational processes and procedures and developing a structured trust framework amongst all users will accelerate deployments and limit conflicts. Increasing the amount of automation through data integration between UTM and ATM systems will be critical to ensure smooth deployments and provide a safe operating environment for all aircraft types.

The current regulatory and standards framework needs to be further developed considering the inputs from all stakeholders and users so as to further enable UAS deployments. Establishment of national frameworks used to support local implementation should inform the development of a global framework.

— END —