Connected Places Catapult

Enabling UTM in the UK

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1 Enabling UTM in the UK

The UK Drone sector is projected to grow rapidly over the coming years, with increasingly capable technology spawning a new range of potential applications and business models. Unlike several frequently hyped technologies, we are already realizing a number of benefits from the application of drones: Visual Line Of Sight (VLOS) inspections are substantially reducing costs of asset inspections in certain areas and removing people from harm's way; their use in photography, surveys, and even search and rescue, is amplifying productivity, accuracy and coverage in each of those areas. Compared to the possible commercial and societal benefits that drones have to offer, the market today represents only the tip of the iceberg.

As we move towards an increasingly automated future, the potential that drones offer increases exponentially – from delivery services through to inspection of infrastructure (Rail, Power, Oil & Gas), highways and construction; the sheer breadth of use cases is remarkable. However, for these applications to operate in a safe and routine manner in increasingly complex environments and in proximity of congested airspace, requires the integration of Unmanned Traffic Management (UTM).

In the Whitepaper '***Towards a UTM system for the UK***' we put forward a conceptual framework for a national Unmanned Traffic Management (UTM) infrastructure and laid out the rationale for why a UTM framework is required in detail, along with several basic principles to be followed in order to leverage the maximum benefits. UTM addresses an existing gap in the infrastructure required to enable the market by delivering on a number of airspace integration requirements for successful operations of drones:

- Collaborative strategic deconfliction
- Well-defined and known airspace environment for situation awareness
- Tactical deconfliction and separation
- Geofencing and restricted zones
- Flexibility in the use of very low-level airspace

As a result of that work, CPC convened a more detailed development of Open-Access UTM to help inform and support the UK Government's objectives [Ref. 1, 3] of creating a shared and integrated airspace for all legitimate users. Crucially, this work brought together expertise from UTM research initiatives in the UK, USA and Europe to help develop the different capability areas of the framework and maintain alignment with these initiatives.

This Open-Access UTM research programme was led by the CPC with the aim of engaging with UTM stakeholders and the wider UAS community to develop and formalise the Open-Access UTM framework, and define the future direction around which industry and regulators can openly engage with each other to explore how UTM may be trialled, de-risked and matured. This report provides an overview of the progress made over the last year together with recommendations to Government, the CAA and industry. It is meant to inform on the UTM research being conducted rather than to present a blueprint for a UTM system therefore it aims to address information gaps and enable informed discussions and engagements.

1.1 UTM Challenges

The development and implementation of a national UTM system rwill require greater industry engagement and activity in order to address the technological, commercial and regulatory gaps. The intensity and extent of BVLOS related research, development and testing and the rapid expansion of the VLOS market in the UK suggests that there are significant benefits for the client industries and for the UAS sector. The industrial benefits include but are not limited to skills, improved safety, reduced operational and data acquisition costs and enhanced operational capabilities. However, the extent to which these benefits are realised will be greatly dependent on overcoming the barriers identified with the help of the industry, the extent to which UTM can be leveraged and the extent to which government and industry efforts are coordinated. To date the CPC has enjoyed broad engagement from the drone industry on developing UTM and we are keen to maintain this as we look to progress the work and consider the wider issues in involved in commercialising UTM.

1.1.1 Ecosystem Complexity

As with any large-scale technology development project, development of a UTM system requires the consensus and collaboration of different stakeholders. This inevitably complicates the design and development process especially with the introduction of automation of traffic functions in a safety critical industry. To overcome these issues, initiating the Open-Access UTM concept design, architectural studies and technology identification has been critical in building consensus thereby reducing the risks associated with future research, informing policy and regulations.

1.1.2 Economics

The development of a robust UTM is a necessary step in unlocking the full potential of the drone market, and unlocking multi-million-pound growth in the UK. However, whilst the benefits are substantial, it is not immediately clear to all parties how the technology, infrastructure and services will be commercialised. In the longer term as we move towards integration manned and unmanned aircraft the costs and benefits of UTM for both new unmanned and existing air users will need to align.

1.1.3 Technology Challenges

The next generation of UTM will result in data-rich and service-driven systems built using large-scale IT infrastructure expertise not dissimilar to that needed to create BBC iPlayer, Facebook or Netflix. Such services measure performance in terms of daily active users, data usage in petabytes and require cyber-security expertise to protect the data and systems. Data protection will become a key component in UTM. To enable advanced drone operations with UTM, there are also challenges of frequency spectrum for command of drones and Detect and Avoid (DAA) which need to be addressed.

1.1.4 Regulatory Challenges

Given the emergent nature of the drone sector, the regulators may struggle to provide regulatory cover as the technology evolves rapidly whilst rulemaking and standards development are progressing in parallel. There is a need to create effective partnerships with the regulator to enable UTM evaluation and testing to share learnings and outcomes.

1.1.5 Safety-Critical Industry

A fiercely protected, and completely justified, safety-first approach to new technologies, software, cyber-security and operations in the aviation industry inevitably becomes a barrier to innovation as it does in many industries with this requirement e.g. rail or medicine. This is purely driven by the increased complexity of testing and slows the speed of progress. It is even more important than normal therefore that this process happens in a coordinated fashion and that industry, Government and the regulator work together to accelerate innovation, within the bounds of safe operation, as much as possible.

The Open-Access UTM programme is one of these collaborations in which government, industry and the CAA have engaged to address issues about ecosystem complexity, technology and regulatory challenges. This has led to a UTM framework for operations of unmanned systems below 400ft. Operations above 400ft when operating in mixed aircraft environments, including manned, presents multiple regulatory, technical and operational challenges such as the air risk relating to separation and collision avoidance. It is therefore necessary to take an incremental approach (as suggested in Figure 1) to advancing UTM for integrating the different types of aircraft and evolve solutions along the way as evidence from trials becomes available.

***Figure 1.** Incremental approach to developing UTM*

Addressing these challenges requires a cooperation between government and industry as well as coordination between a number of forums and initiatives e.g. DfT and CAA working with industry through Airspace Modernisation Strategy and the Innovation Sandbox, partnering with BEIS and CAA on the Pathfinder Programme[1] or BEIS working with the Drone Industry Action Group (DIAG)[2] and the Future Flight Challenge. These examples illustrate how there is a level of cooperation on UAS integration– this level of activity is now needed on UTM to enable the next acceleration in UAS integration.

1.2 Open-Access UTM

The unmanned aviation industry in the UK and globally has seen significant growth over the last few years, as predicted by several market assessments, and will continue to grow as different sectors engage with it. In particular, as drone services are adopted by various sectors, there is greater demand for access to non-segregated airspace below 400ft. *The scope of the UTM system is as follows:*

1. Initial UTM assumes Very Low-Level (VLL) Operations (<400ft).
2. UAS < 20kg.
3. Traffic services are digital and automated.
4. Drones will be electronically conspicuous.
5. Support nominal and emergency scenarios.
6. UTM does not require the establishment of new airspace classes although there is a need for greater awareness and adjustment in the aviation community that operates below 400ft.

It is assumed that underpinning technologies and automation capabilities necessary for UTM can be developed and built such that the expansion of drone operations in airspace meets the acceptable levels of safety set out at the national level[3]. Further, as Open-Access UTM is developed, it will be aligned with internationally recognised UTM-related standards in terms of the traffic services, processes and data requirements that it supports.

RESEARCH AREAS	DESCRIPTION
UAS integration in airspace	There are numerous challenges in the way of operating and integrating UAS into the airspace including technology solutions for separation and collision avoidance, lack of spectrum for Command and control, regulatory framework and UTM. The activity should also focus on what changes are needed to manned aviation e.g. electronic conspicuity for all.
Advancing UTM for all UAS aircraft	More research and development is needed to advance UTM to support more classes of unmanned aircraft.

***Table 1.** General UAS research areas*

[1] Government Drone Pathfinder Programme *https://cp.catapult.org.uk/case-studies/pathfinder/*
[2] BEIS DIAG *https://www.arpas.uk/drone-iag/*
[3] *https://www.caa.co.uk/Safety-initiatives-and-resources/How-we-regulate/State-safety-programme/Policy-and-resources/State-safety-objectives/*

1.3 Participants

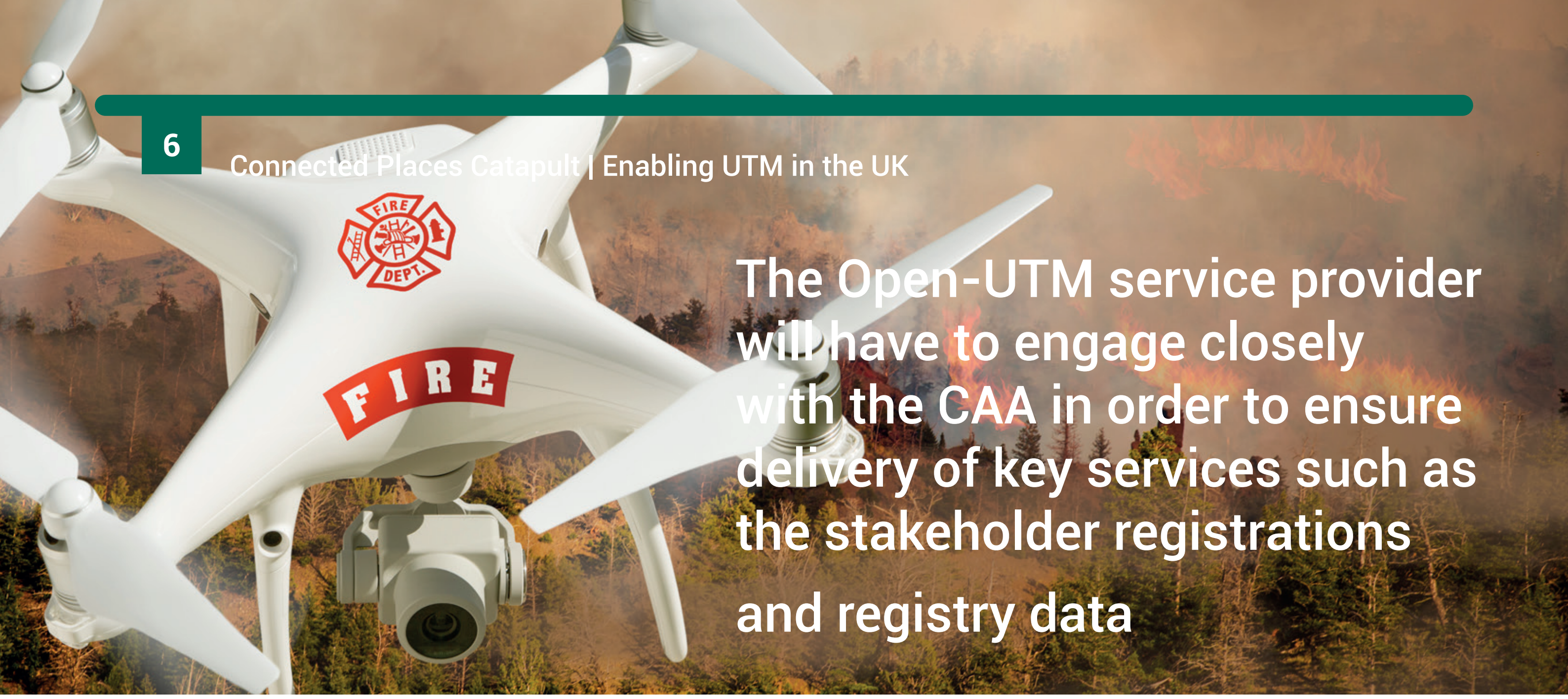
UTM participants can be grouped according to their engagement with the system. The UTM system requires cooperative participation in which stakeholders are guided by regulatory, technical and operational rules.

1.3.1 Open UTM Service

The Open UTM Service (previously known as the UTM Core) is an entity, managed by service providers, which sits at the intersection of many service interactions between UTMSPs and others to facilitate the exchange of data. It has several roles chief being an interface for the CAA to access and share regulatory data with all participants and provide a discovery function (a facility similar to a telephone exchange) for service provider IT systems to be able to link to create a connection for data exchange.

There is a need to address how the service could be distributed across the country – it is unlikely that multiple Open-UTM services are co-located in the same region. The content and information must be synchronised to ensure that all users have access to the correct information. The Open-UTM service provider will have to engage closely with the CAA in order to ensure delivery of key services such as the stakeholder registrations and registry data.

Open-UTM service functions can be grouped into primary and additional: primary functions result in new services which were created for UTM and are necessary components of UTM; additional ones are UTM-related functions which are being brought together into a UTM ecosystem to take advantage of new IT capabilities which can help deliver enhanced services. The CAA already provides some of these functions however the following is a provisional list for discussion.



The Open-UTM service provider will have to engage closely with the CAA in order to ensure delivery of key services such as the stakeholder registrations and registry data

Primary Functions

- Maintains a record of stakeholders and their regulatory permissions – this service is connected to the CAA's core functions of assessing and approving permissions, the data for which is held by the CAA.
- Provides service provider registration/validation capability.
- Provide a discovery service by which to enable a range of interactions.
- Monitors regulatory- level data and maintains a transaction repository for interactions involving the Open-UTM service.
- Provide the regulator with a means of accessing UTM data in order to provide effective oversight of the system and the actors.
- Ensures that valid data relating to supporting services such as aeronautical information and static/dynamic data sources regarding flight restrictions, obstacles, and other flight-critical geographic information are used for UTM operations.

  Today UTMSPs access aeronautical information, NOTAMs and FRZs, from approved (or regulated) providers, to build services for their subscribers. This electronic system is based on a subscription basis to ensure that updates can be pushed out or pulled by the UTMSP as necessary. However, there may be a need for an independent service which can check that the extant data or correct information is in use say in a completed flight plan.
- To support a link between the manned and unmanned traffic management systems.

Additional Functions

- Support a registration gateway for UTM participants.
- Provide the regulator with a means of disseminating regulatory notices and information – today, CAA's Skywise (skywise.caa.co.uk) system provides a means to stay current with news and alerts. It also supports a separate subscription service to provide access safety-critical information, notices and updates.
- Support a repository of Open-UTM information e.g. IT communications and data standards, service support information. This includes a directory service of registered service provider to help end-users to find and sign-up with relevant service providers.

The major global UTM initiatives have identified the need for a common shared resource of information. The EASA U- space framework (Opinion 01/2020, Ref. 4) proposes the Common Information Service which is similar to the Open-UTM construct. The Flight Information Management System (FIMS) addresses information exchange between the FAA and UTM participants including sharing of airspace information and providing access to the UTM system [Ref. 5].

1.3.2 UAS Operators

There are two types of UAS Operators considered: the drone pilot and the operating organisation. The operator could be an infrastructure owner such as Network Rail or Highways England, or employs a commercial entity providing aerial services which employ pilots to conduct flight operations or a recreational model flying club. This creates two levels of responsibility that may need further regulatory considerations. The UK mandated user registration[4] to fly drones weighing between 250g-20kg from 30th November 2019 which applies to recreational users (Flyer ID) and the commercial user (Operator ID – operators can be a person or organisation). This is in addition to the Permission for Commercial Work (PfCO[5]). For simplicity, we have adopted the term operator to refer to the person or the organisation.

The UAS operator has a duty of care for ensuring they obtained permissions from the CAA, has subscribed to use the appropriate services including UTM services, insurance etc and are aware of rules when planning and executing operations. For example, it is important for UAS Operators to be aware of airspace rules and aeronautical information as well as familiarity with controlled airspace rules for safety reasons.

Future UAS operations are likely to become increasingly complex in nature, and as the number of UAS operations increases and the sector matures, the UAS Operator may become subject to additional requirements and responsibilities that reflect the nature of their operations and the vehicle performance.

1.3.3 UTM Service Providers

UTM Service Providers (UTMSPs) enable UAS Operators to safely and efficiently operate in the national airspace. There is a need to consider different categories of UTM service providers to cater for the breadth of airspace stakeholders who need to engage with UTM e.g. business, local councils, emergency services, recreational users, the public, military and ATM.

The main responsibilities of this provider are listed below:

- Validate operator information and details (e.g. operating license, insurance, registration information). Some of these might be validated prior to flight planning and/or activation.
- Provide UAS Operators with a digital system to plan flight operations such that flights are not scheduled to conflict with other manned or unmanned flights.
- Support the submission, strategic deconfliction and activation of flight plans as required by the Open-UTM system.
- Provide UAS operators with situational awareness data and a set of support services during operations.
- Provide flight monitoring and enable the communication and notification of subscriber disruptions and emergencies.
- Support the use of supplementary data through connections to Supplementary Data Services. The operator might have access to supplementary services without the interaction with a UTMSP, however, in some cases, such as the flight planning, the link between insurance providers and individual UTMSPs is necessary to provide verification as to whether or not an operator has adequate cover for their proposed mission.
- Log operator flight data and archive operations data for analytics, regulatory and operator accountability purposes.

1.3.4. ATM Service Providers

Air Traffic Management Service Providers (ATMSPs) will have the responsibility to manage manned aviation of all types in designated classes of airspace and will have the power to approve or deny any UTM activities that are deemed to interact with the ATM activities. Therefore, ATMSP is required to interface with UTMSPs, through the ATM/UTM interface and OUTMSP Services gateway, to assure safety – particularly within the vicinity of ATZ of airports, as well as throughout controlled airspace. The ATMSP might consist of the ATC and/or authorised service providers, such as ANSP, UTMSP, SDSPs, depending on the capabilities (i.e., specific services and functions) of the given CTR. ATM services are considered separate though complementary to the services provided by UTM service providers.

The key capabilities and responsibilities to be maintained by ATMSPs are:

- Monitor conventional manned air traffic.
- Communicate received unmanned air traffic information to relevant ATM stakeholders as and when necessary.
- Provide permissions to UAS operations when operating within flight restriction zones (FRZ). The Open-UTM service provider will have to engage closely with the CAA in order to ensure delivery of key services such as the stakeholder registrations and registry data.
- Communicate air traffic information, including contingency and emergency plans for their FRZ, to UTM stakeholders as and when necessary.

[4] Flying drones and model aircraft *https://register-drones.caa.co.uk/drone-code/getting-id-before-you-fly*
[5] *https://www.caa.co.uk/Consumers/Unmanned-aircraft/General-guidance/Drone-operators-with-a-valid-CAA-permission-for-commercial-work/*

1.3.5 Civil Aviation Authority

It is expected that the CAA will provide safety oversight and lead on regulatory framework for the UTM system, service providers and oversight of the different services in order to protect the public and consumers of UTM services. This will include guidance about the appropriate levels of safety, development of approvals, licences and registration for UTM participants (including drones).

Other stakeholder groups with whom the CAA will interact about UTM are Drone manufacturers, Standards bodies, and manned aviation groups (commercial and general aviation). Military stakeholders will have a need to consume planned drone operations and communicate their planning to ensure effective low level deconfliction and this can be achieved through the ATM interface.

The CAA also has a critical role in determining the delivery of Open-UTM services.The primary services have a key role to play in enabling participants to be able to identify and validate, connect to and share data with other participants. Bringing the additional services into the Open-UTM service provides a pathway for the CAA to pool UTM related activities and deliver via a single system. These additional services are not discussed as part of the architecture to simplify the discussion of the main UTM system.

Clearly, there are direct relationships between some services e.g. stakeholder applications, Directory services and the Stakeholder registrations (used to validate credentials) and decisions to be made about how to implement these including the provision of credentials security.[6]

1.3.6 Public Authorities

Public authorities include national and local authorities, such emergency services and local authorities that are expected to play necessary roles to coordinate access to airspace or potentially impact operations.

Public authorities specifically the UK Emergency Response and Recovery have a joint operational model for the use of an aerial service. This service is distributed across the country and is able to coordinate emergency operations with the local and national air traffic services. The Open-Access UTM programme has taken this into consideration when considering the use of dynamic restrictions to support emergency operations.

Key capabilities and responsibilities to be maintained by public authorities include the following:

- Emergency services operations will be deployed and operate with a higher priority. To achieve this, they might be engaged with a UTMSP that provides relative services.
- Approved authorities will be able to use UTM services to generate dynamic flight restrictions.
- Authorities may implement legislation and enforce regulations.
- Access flight log data and other relevant information stored on the UTM systems when required.

1.3.7 Supplementary Data Service Providers

Supplementary Data Services Providers (SDSPs) offer additional information services that will typically support a UTM actor to plan, validate and verify information, or inform a decision-making process.

Examples of SDSPs will include:

- Weather services.
- Insurance services.
- Geographical information services (terrain and obstacle data).
- Surveillance data (e.g., ADS-B).
- Telecommunication services (e.g., LTE,5G, Private Network, etc.)
- Aeronautical Information Service (AIS) together with authorised data providers.

Notably, these services may be accessible by the UAS Operators and Open UTM services independently. Information from these entities is expected to flow through individual UTMSPs and be disseminated to the greater ecosystem, as necessary, to follow an informed decision-making and approval process of a flight operation. Furthermore, insurance organisations maintain the responsibility to insure individual pilots, operators and third parties during the duration of their missions.

[6] ICAO Trust Framework ***https://www.4.icao.int/ganpportal/trustframework***

1.3.8 Public Users

Public users, also called a member of the general public, is added to the Open Access Architecture. Given the breadth, scope and level of access assigned to this user, the recommended connection from this actor to one within the defined architecture, is a connection with the UTMSP. Similar to the Public Safety user, the Public user will require local data provided on a handheld mobile device through an interface of their choice; this is best handled by the market. For example, the public might use a Remote ID application provided by a UTMSP to identify operations in certain geographic areas. One marked difference between the Public and Public Authority users is access to UAS Operator data, as this will be reserved for authorised Public Authorities. Furthermore, unlike Public Authorities, the Public user will not have the authority to create Airspace Restrictions.

1.3.9 Unmanned Aircraft

Unmanned aircraft will have to be made to regulatory requirements e.g. equipment standards prior to being operated in a UTM environment. UAS aircraft will have to support electronic conspicuity and geofence technologies in addition to typical health information about Command & Control (C2) link, GNSS link status and battery health to name a few. Today, UAS are remotely operated by a pilot who acts as the decision maker – increasing automation levels opens-up UAS-based decision-making possibilities either to supplement UTM services or provide new ones.

1.4 UTM Services

The following section provides a high-level description of services considered in the Open-Access UTM environment which will be provided by the different service providers (UTMSP, ATMSP, SDSP, OUTMSP) to support the needs of the participants. In our previous report, we described user-journeys for the UTM service provider during the three flight phases; Pre-flight, In-flight and Post-flight.

The list of services is not exhaustive, and it is expected that UTM will adopt new services as UTM matures and evolves.

1.4.1 Stakeholder Registration

There are potentially 4 types of registrations required by the Regulator which must be completed prior to joining the UTM network and there may be a cooling-off period before the data is available and accessible in the system.

1. Unmanned aircraft
2. Remote Pilot in Command
3. Operator (where necessary separate to Pilot registration)
4. Service Providers namely UTM SPs, ATM SPs and SDSPs)

The Regulator will maintain a detailed registration record in its databases. The UTM system should uniquely identify every registered user therefore there is a need for portions of the Regulator's registration data to be shared with the Open-UTM registry. It Is assumed that this data consists of a unique identifier which captures information about the end-user, service provider, permissions and any endorsements. It will enable the authorised service providers and authorities to make a formal request through the "Stakeholder Validation" service. There is a need to build global and regional consensus on the delivery of registration service which ensures data protection and harmonisation.

Public user will require local data provided on a handheld mobile device through an interface of their choice; this is best handled by the market.

Participants may initiate flight planning through service provider UTM software or other available software which enables the creation/modification, submission and activation functions.

1.4.2 Stakeholder Validation

This service provides the ability to check a participant's credentials. The use-cases for this service can be related to the number of UTM services and depend on the task to be completed e.g.

- UTMSP will check user/operator permissions when they register new customers or partners.
- Flight plan submitted for approval.
- UAS identification.
- Open-UTM service may run regular checks of service provider permissions.

1.4.3 Flight Planning

Participants may initiate flight planning (VLOS or BVLOS) through service provider UTM software or other available software which enables the creation/modification, submission and activation functions. Flight planning tool should account for general airspace conditions as given in the aeronautical information, air traffic and weather, mapping (terrain, obstacles) etc in order to generate an operational volume. This could be the traditional 4D flight plan covering a point to point trajectory or an area-based plan. The output of this is an electronic flight plan (FPL) which can include digital signatures ascribing its integrity, sender authentication and version numbers for information used e.g. Aeronautical information. A flight plan will consist of several layers of information – required or regulated data would be shared with others whilst proprietary data is only shared between the operator and UTMSP.

A key process following the planning and submission of a flight plan or intent is the Flight approval (clearance) process. UAS flights can only be conducted after a flight or operational plan has been submitted, in case of controlled airspace authorised, and approved. The flight approval service encompasses multiple steps and calls on other services – the critical service is the strategic deconfliction service which provides the ability to detect and resolve intersections between flight plans. It is expected that the UTMSP will be responsible for a bulk of this activity with support from the Open-UTM service.

1.4.5 Flight Noticeboard

The Flight Noticeboard is required to hold operational data (e.g. planned, active, terminated) – this includes contact data for originating UTMSP but also the flight plan. There are different options for storing flight operations e.g. origin-waypoints-destination, operational volumes or a combination. *The Flight Noticeboard as a service may have the following functions:*

- Uses the Discovery service to enable parties to lookup flight plans by geography – one approach is to use the Discovery to identify active UTMSPs to enable direct engagements with the UTMSPS.
- Repository of flight plans (planned, approved, active and terminated).
- Provides a mechanism for reprioritising flights and notifying service providers of changes to plans.

1.4.4 Discovery

There is a need to identify planned operations in a region in order to be able to deconflict new flight plans. The Discovery service interacts with the Flight Noticeboard to identify such regions in response to a request from UTMSPs either by submitting a flight plan or by submitting a request to look-up a location. The service can respond with details of which UTMSPs to contact. The Discovery service also supports other services that require the identity of active UTMSPs perhaps to send alerts with regard to drone emergencies, electronic identification or dynamic restrictions being created.

Therefore, the discovery service ensures visibility and use of information which is common to flight operations and that can help with collaborative decision-making. A particular implementation of this service concept is the ASTM[7] Discovery and Synchronisation Service (DSS) which was first published in the Remote ID-standard (Ref. 23).

[7] ASTM F38 committee is supporting the creation of standards for UAS and UTM

1.4.5.1.1 Discovery and Synchronisation

ASTM's DSS standard is designed to support inter-UTMSP communications (Figure 2) in a federated UTM system in order to accomplish various tasks. To support these functions, it holds a directory of registered service providers (ensure only approved providers can use the service) and a digital map of the local region which is used to identify active operations (service area) – shared airspace concept (Figure 3).

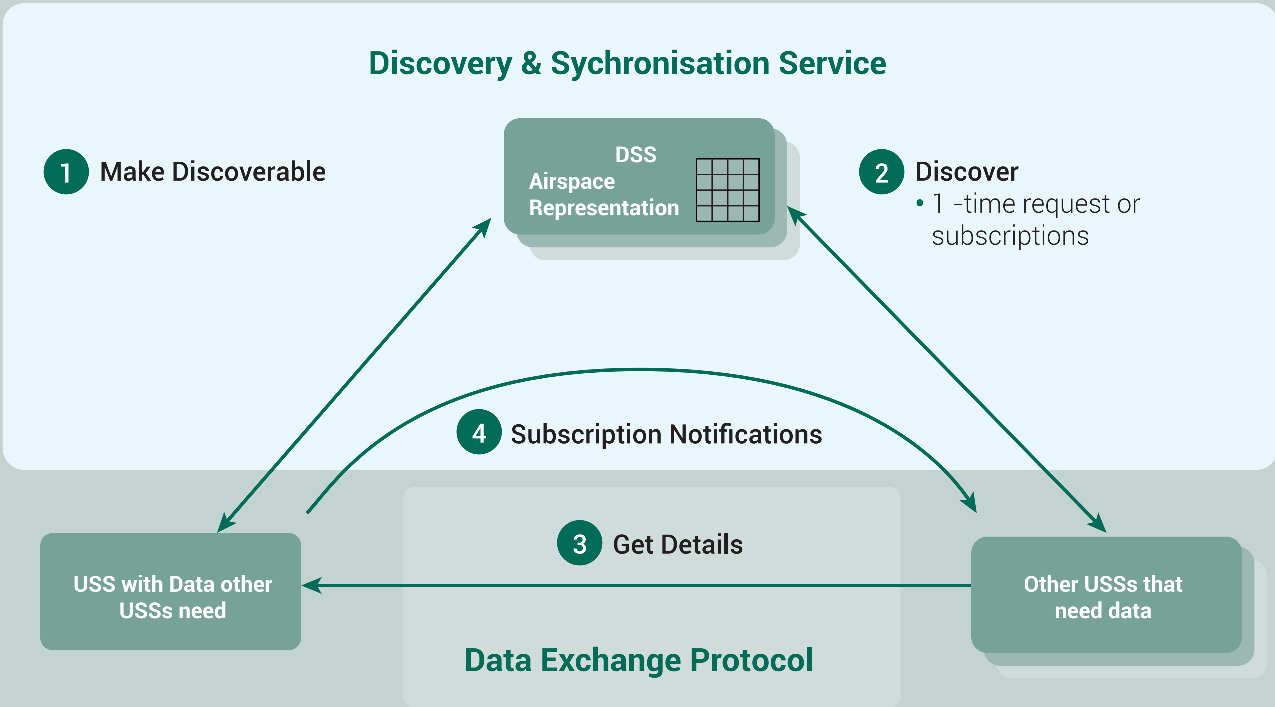


Figure 2. ASTMs DSS Interoperability Design (courtesy of ASTM F38 committee)

The Service has the following functions:

1. **Discovery** – uses the airspace representation to enables UTMSP to identify other UTMSPs who are active in the area of interest.
2. **Synchronisation** – For a given area, all interested UTMSPs have to engage with the DSS service to enable them to connect with each other, exchange data between themselves (UTMSP to UTMSP) and reach agreement e.g. deconflicted flight plan. The service only facilitates the connection and is the final arbiter on conflicting changes occurring simultaneously.
3. **Notifications** – enables alerts and updates to be cascaded quickly to active UTMSPs.
4. **Interface** – the service has an associated standard for communication and data protocol and agnostic of UTMSP technologies.

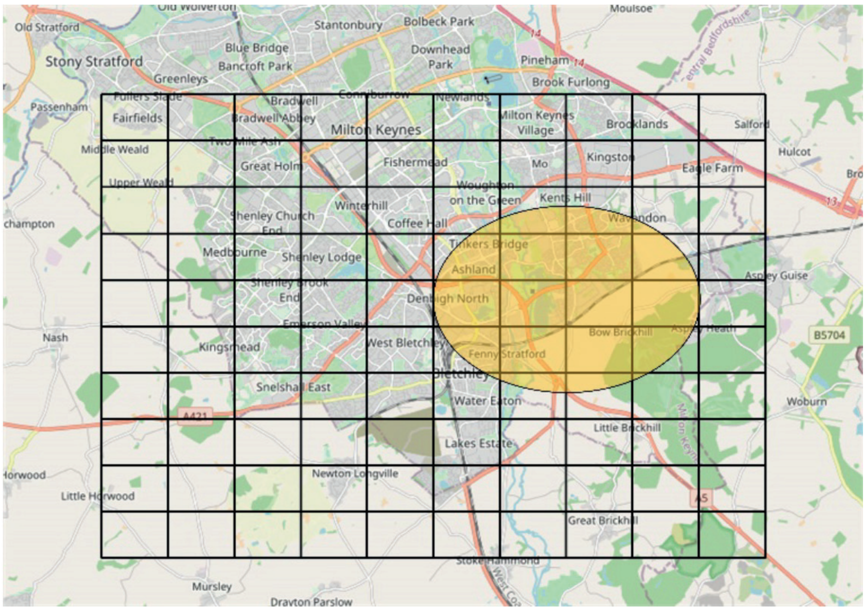


Figure 3. DSS concept for Shared Airspace Representations

1.4.6 ATM Interface and Permissions

ATM Interface is proposed as an independent entity that would act as a "regulated" standard interface to support a common service for all airports & FRZ's in the UK. This would provide all participating FRZs with the uniform access open- up opportunities for drone operators. This by no means excludes UTMSPs from directly working with airfields and FRZ's or even exclude the developments of other interfaces that cater to different types of airfields and FRZ's. For the purposes of this research, one interface has been investigated in order to understand the requirements.

The service provides the following functions:

- Maintains a directory of airports and Flight Restriction Zone service providers.
- Enables the routing of flight operations to the appropriate airfield or FRZ service provider.
- Supports the communication of flight plan modifications and approvals.
- Maintains a record of flights (planned, active, terminated).

1.4.6 Dynamic Restrictions Management

A dynamic restriction is a type of airspace constraint, defined using geo-fence technology, that can be used to clear relatively small pockets of airspace at low altitudes of UAS, such that priority operations of manned aircraft, unmanned aircraft, or ground-based entities can be performed without the potential for interruption by nearby UAS that are not participating in the priority operation.

This service will have the following functions:

- Be able to accept and approve digital flight restriction data.
- Be able to apply operational priorities to flight restrictions.
- Support both urgent and normal flight restrictions.
- Communicate flight restriction data with affected service providers.
- Log flight restriction data.

1.4.8 Conflict Management Services

The major objective of a UTM will be to ensure UAS operations are free of intersections with all other known operations and hazards including obstacles, terrain, and weather. This is to be achieved through a layered approach consisting of strategic deconfliction (pre-flight planning) following by tactical deconfliction and collision avoidance strategies [Ref. 5]. There remain a number of gaps in the UTM conflict management framework e.g. UAS rules of the air and vehicle-based collision avoidance resolution.

1.4.8.1 Strategic Deconfliction

This layer is provided in the pre-flight planning phase to ensure that the planned 4D flight volumes are unique to each operation, have considered known hazards and enable UAS to be strategically separated. This service is initiated by Discovery service and contributes for the flight plan approval process.

1.4.8.2 Tactical Deconfliction

This layer caters for in-flight conflicts starting with potential violations of operational volumes to collision avoidance. This service is supported by the ***Monitoring and Alerting*** and ***Dynamic Re-route*** services. This tactical deconfliction capability ensures conflicting en-route volumes are re-routed by updating the respective flight plans. If the conflicting volumes cannot be re-planned, tactical Monitoring & Alerting and Detect & Avoid are implemented. In this context, detect and avoid refers to how the UTMSP uses operational data to identify and resolve conflict to remain clear of other users.

1.4.8.2.1 Monitoring and Alerting

Each UTMSP is responsible for monitoring the performance of client operations and alerting flight owners and other airspace users when off-nominal conditions (i.e. off-plan) are detected.

The service has the following functions:

- When higher priority operations are detected, the service should alert client UAS Operators of the change.
- Monitor airspace conformance (e.g., when UAV is out of planned volumes such as the conformance geography).
- Inform UAS Operator and inform/alert other airspace if required when a UAS leaves its planned volume.

The Monitoring and Alerting Service may utilise several resources or sub-services that include the following but could be extended to other data and services,

- C2 / Link health.
- Navigation system health.
- Environmental conditions (Weather, Electromagnetic Interference etc.).

1.4.8.2.2 Dynamic Re-route

Dynamic re-routing is the primary conflict resolution strategy when operational volumes or volume intersections are predicted by the monitoring service of the possibility of conflicts leading to collision.

The service functions in all situations while the conflict is a long distance away and should be able to:

- Propose alternative routes or landing areas,
- Might apply priority rules to affected operations.

The issue with re-routing is the need for systems to collaborate in building consensus on new routes. The missing link in this collision avoidance strategy is the lack of rules of the air for UAS which would reduce the time needed to build the consensus. Although not critical today, as traffic density increases, it will be necessary to build a consensus on the UAS rules of the air.

The major objective of a UTM will be to ensure UAS operations are free of intersections with all other known operations and hazards including obstacles, terrain, and weather.

1.4.9 Electronic Identification (E-ID)

Electronic conspicuity is critical to enabling UAS operations in airspace. It is a broad term covering a range of technologies which at the basic level provide electronic identification and positional information to help create a known environment for the users. Electronic identification will make it possible to identify aircraft, the flight status and the operator/pilot by relating digital markers with the registration data.

There are two possible implementations in discussion today:

- Direct Identification in which the drone broadcasts a signal which can be received by other devices. The message in the signal may be used to request further information from service providers.
- Network-based identification, which uses tracking information generated by the responsible service provider to identify the drone based on location.

E-ID should support the following functions:

- Provide validation of UAS identity.
- Support the provision of flight and plan parameters.
- Upon request, support role-based access to E-ID data.

Electronic Conspicuity is critical to enabling UTM. While there are emerging standards in this area (e.g. ASTM F38 Remote ID) or uncoordinated use of ADS- B type surveillance technologies, research into both broadcast and network identification solutions are required to address the different EC use-cases.

Electronic conspicuity is critical to enabling UAS operations in airspace

1.4.10 Tracking & Surveillance

Tracking and Surveillance Exchange services enable the UAS Operator and other airspace actors e.g. ATMSP to maintain a common situation awareness by providing the following:

- Surveillance/position data exchange between SDSP, UAS Operator, and UTMSP.
- Fusion of multiple tracking data sources.
- Positive tracking of active/operating aircraft.

Each UTMSP is responsible for providing a clear, authoritative surveillance picture to their clients. This picture is constructed by fusion of various data streams, originating with the UAS Operator and various SDSPs – it is expected that UTMSPs will maintain an authoritative tracking picture and may have to share a coarse subset with the Flight noticeboard to support general air traffic requirements. Certain participants e.g. the Regulator and FRZ authorities, may have to be provided with privileged access to this data.

1.4.11 Flight Termination

Once the flight has concluded, the RPIC notifies the UTMSP of notification either manually or automatically. Then the UTMSP communicates flight termination notices to services within the Open UTM Service (such as FNB), and notifies all affected parties of the completion of the mission and also to deregister any relevant subscriptions e.g. NOTAMs in the region if no further operations are planned there under that UTMSP's management. The flight logs are subsequently stored and in the case of unscheduled terminations or emergencies, corresponding actions are undertaken (as defined by the regulator).

1.4.12 Audit

The Audit function will be required in support of regulatory functions to review interactions between actors to ensure the system is appropriately used, managed and safeguarded, and that the actors and stakeholders involved are undertaking their responsibilities as defined by the regulator.

1.4.13 Accident and Incident Reporting

This is a UTMSP or SDSP service based on Regulator guidance that enables the UAS Operator to report an accident or an incident to the Regulator.

1.4.14 Digital Logbook

The digital logbook is a UTMSP or SDSP service that enables the UAS Operator to record safety compliance and performance, flight records, maintenance, malfunctions, accident, incidents, and emergencies.

1.4.15 UTMSP Handover

UAS will start and complete a mission with the same UTMSP. UTMSP handing off a UAS flight to another UTMSP while airborne may eventually come with cross border or out-of-region operations.

This selection of UTMSP or SDSPs is likely to be subject to key market drivers, including whether the service provider provides regional or national UTM coverage (and maybe in the future, cross-border capability), whether operators might require UTMSPs capable of managing sensitive information (e.g. relating to military or emergency services), or whether UTMSPs enable unique and beneficial operating capabilities.

1.4.16 Supplementary Data Services

There is a range of data requirements for flight operations which could be offered as services.

- **Aeronautical Information Services** – The UTMSP receives aeronautical information data from a SDSP and uses it for multiple services.
- **Weather** – The UTMSP receives weather information from a SDSP and uses it the monitor service while in-flight.
- **Navigation Infrastructure Service** – The UTMSP receives navigation infrastructure information from a SDSP and uses it for conformance monitoring.
- **Communications Infrastructure Service** – The UTMSP receives communications infrastructure information from a SDSP and uses it for the conformance monitoring.

RESEARCH AREAS	DESCRIPTION
Electronic Conspicuity (EC)	Effective solutions for EC both broadcast and network remain barriers for UTM.
Air Traffic and Deconfliction	More research is needed into solutions for an independent pre- light deconfliction capabilities including the use of 'flight noticeboard' concepts.
Services Framework	As many of the UTM capabilities (service automation) are outside of the main aviation system there is need to consider how these fit the regulatory model.

Table 2. UTM Services related research areas

2 Architectural Options

We presented the architectural concept in the UTM white paper to illustrate how the stakeholders might be organised to enable the relevant communications and data-exchange activities. In this initial view (Figure 3), the Open UTM Services was placed at the centre in a manner which allowed the sharing of a set of information (Registration, Flight noticeboard, ATM permissions) – The Open-UTM Service concept is similar to the U-Space Common Information Function (CIF)[8] which is described by EASA as an access point for information for UTM participants.

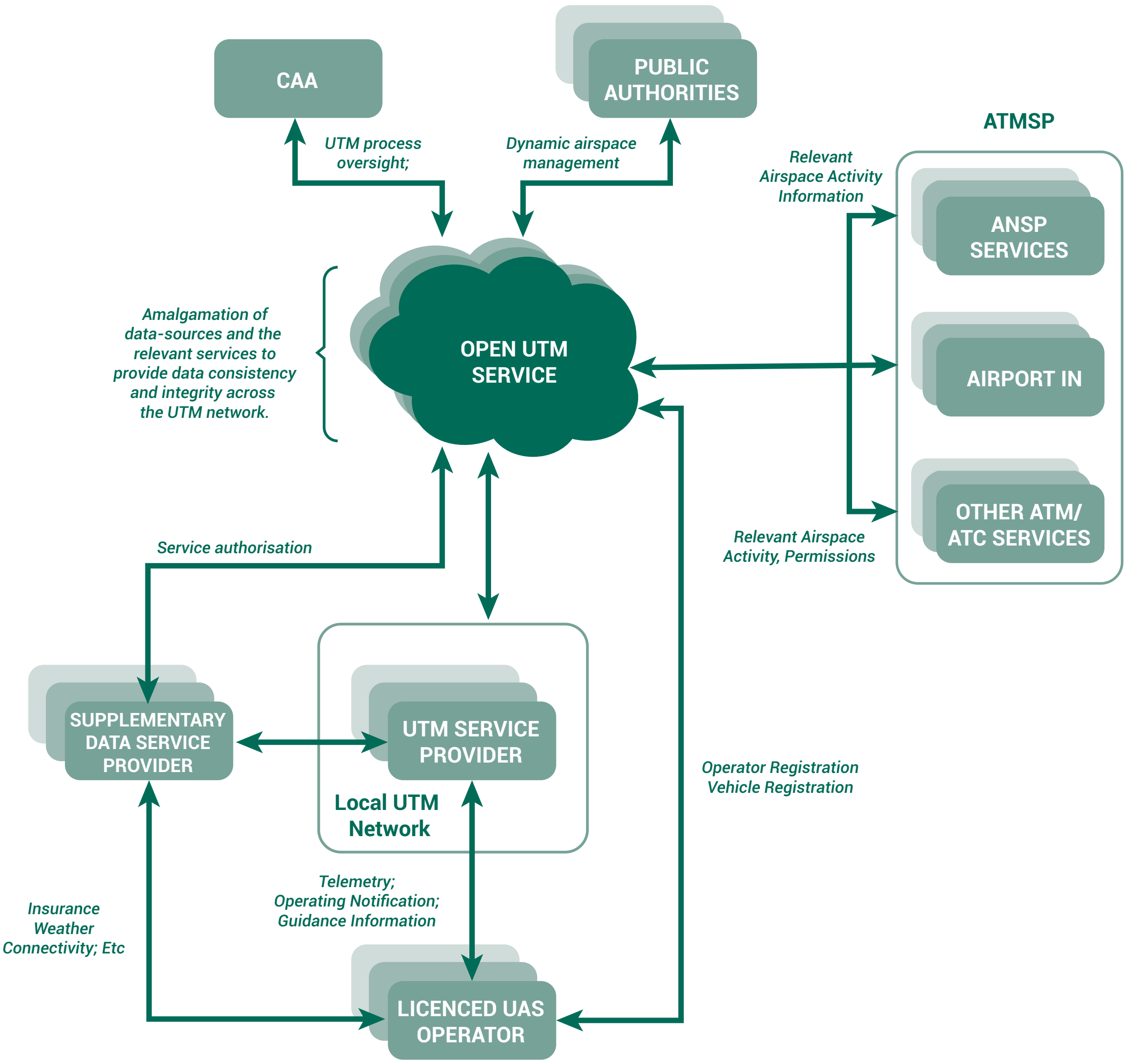


Figure 4. *Open Acces UTM Concept*

[8] https://www.easa.europe.eu/document-library/opinions/opinion-012020

Figure 4 illustrates the initial Open-Access UTM architecture developed by the consortium in Phase 1. While there appears to be a degree of federation of major regulated services, variations of the architecture exist that are consistent with the Open-Access UTM principles – the starting point for a multiple service provider framework has to be a distributed architecture to allow the creation of new opportunities for businesses and create the conditions to accelerate innovation.

From this starting point, it is also important to consider the variations of architectural options to help build-up information and evidence for the way forward – of course one of the options has to be selected for test and evaluation in order to de-risk and mature UTM concepts.

2.1.1. Points of Interaction

Across the architecture, there are the following points of interactions:

1. **CAA – UTM participants:** Participant interactions with the CAA via an Open-UTM registration service – this could be considered optional although with time the system will need to be connected to the stakeholder validations service.
2. **CAA – UTM system:** The regulator requires a connection into the system to provide effective oversight of airspace and operations through sharing regulatory directives, information and notices and access air traffic data from the flight notice board. It is assumed that the regulator publishes airspace information via the Aeronautical Information Services (AIS) therefore the regulatory directives are safety related.
3. **UTMSP – Drone Operators:** The UTMSP and drone operator interact digitally throughout the lifecycle of a flight. This market element of UTM services will have to meet the needs of customers. While the industry is already taking a lead on the development of digital platforms and services offered to end-users, the industry will have a duty of care in regard to regulations e.g. provision of accurate information and ensuring equal access.
4. **UTMSP – The Open UTM Service:** The UTMSP engages with the Open-UTM service to accomplish a range of tasks in support of drone operations including facilitating engagements with other UTMSPs or ATMSPs. A key interaction of the Open-UTM service is the use of the discovery and Flight Noticeboard to help UTMSPs to work collaboratively to delivery in-flight services based on who is affected in the operational area. This is a critical interaction in UTM as it enables data-checking and follow-on transactions between service providers.
5. **UTMSP – SDSPs:** UTMSPs are expected to engage with authorised SDSPs to improve their service offerings. This is expected to occur on an open-market basis, with the UTMSPs free to work with relevant data and service providers to deliver better services to their customers.
6. **UTMSP – UTMSP.** UTMSP interactions are expected to form the bulk of the data-exchanges within the framework. UTMSP will engage with other UTMSPs to fulfil a range of tasks associated with service provision. The service providers are also able to negotiate directly with each other if needed. To engage with the UTMSPs, a UTMSP would be expected to engage with the Discovery service to determine communication details of the target UTMSP(s) in terms of service endpoints.
7. **UTMSP – ATM Interface:** The UTMSP shared operational data via the ATM Interface service which is specifically designed to support information exchanges with airports and ANSPs. The service will also provide a data management facility as a means of delivering general air traffic data to the manned ATM operation.
8. **Public Authorities – Open-UTM Service:** Authorities such as the Police and Fire services will raise dynamic flight restrictions which may be cascaded via the Open- UTM service or enabled by an appropriately authorised UTMSP.

2.2 Degree of Federation

Two versions of the federated architectures can be visualised depending on how functions are to be distributed between the Open-UTM Service and the UTMSPs. The distribution of services will depend on the role of the Open-UTM service and will change some of the interactions between participants. Table 3 illustrates the two versions of architecture of how services can be distributed with the differences highlighted in italics.

SERVICES	ARCHITECTURE TYPE		PRE-FLIGHT	IN-FLIGHT	POST-FLIGHT
	CENTRALISED	FEDERATED			
StakeholderRegistration	Open-UTM SP	Open-UTM SP	✓		
Stakeholder Validations	Open-UTM SP	Open-UTM SP	✓		
ATM Interface and Permissions (see 1.4.7)	Open-UTM SP	UTMSPs, Interface service providers	✓	✓	
Flight Notice Board	Open-UTM SP	Open-UTM SP	✓		
Discovery	*Open-UTM SP*	*n/a*	✓		
Discovery and Synchronisation[9]	*n/a*	*Service Provider*			
Flight Planning	UTMSP	UTMSP	✓	✓	✓
Dynamic Restrictions Management	*Open-UTM SP*	*UTMSP*	✓	✓	
Strategic Deconfliction	*Open-UTM SP, UTMSP*	*UTMSP*	✓		
Monitoring & Alerting Service (Tactical Deconfliction)	UTMSP	UTMSP		✓	
Dynamic Re-route (Tactical Deconfliction)	UTMSP	UTMSP		✓	
Electronic Identification	UTMSP	UTMSP		✓	
Tracking and Surveillance	UTMSP / SDSP	UTMSP / SDSP		✓	
Flight Termination	UTMSP	UTMSP			✓
Accident and Incident Reporting	UTMSP	UTMSP			✓
Digital Logbook	UTMSP	UTMSP			✓
Audit	CAA / SDSP	CAA / SDSP			
Handover	UTMSP	UTMSP			
Supplementary Data Services including AIS, Weather, Terrain & Obstacle Maps	SDSP	SDSP	✓	✓	

Table 3. Open-Access UTM Framework Services

[9] This is an ASTM standard for UTMSP interoperability for communications and data-exchange

2.2.1 Semi-Federated

This architecture was proposed in the previous Open- Access UTM report in which support for public authorities and ATM were aggregated into the Open-UTM service with multiple-UTMSPS facilitating majority of services. Majority of communications occurs via the Open-UTM service.

The UTMSPs remains central in this approach and engages closely with the Open- UTM service to enable data validations and request/submit information on behalf of the operator. We described earlier the points of interaction Section 2.1. The architectural interactions from the UTMSPs perspective are shown in Figure 5.

There are three groups of services required by all UTMSPs are aggregated together in the Open-UTM service.

- Regulatory services made up the Registration and validations and Directives.
- Operational made up of Discovery and Flight Noticeboard.
- ATM Interface and Dynamic Restrictions.

The regulatory services need to be shared via Open-UTM services as these provide a point of reference for all UTMSPs.

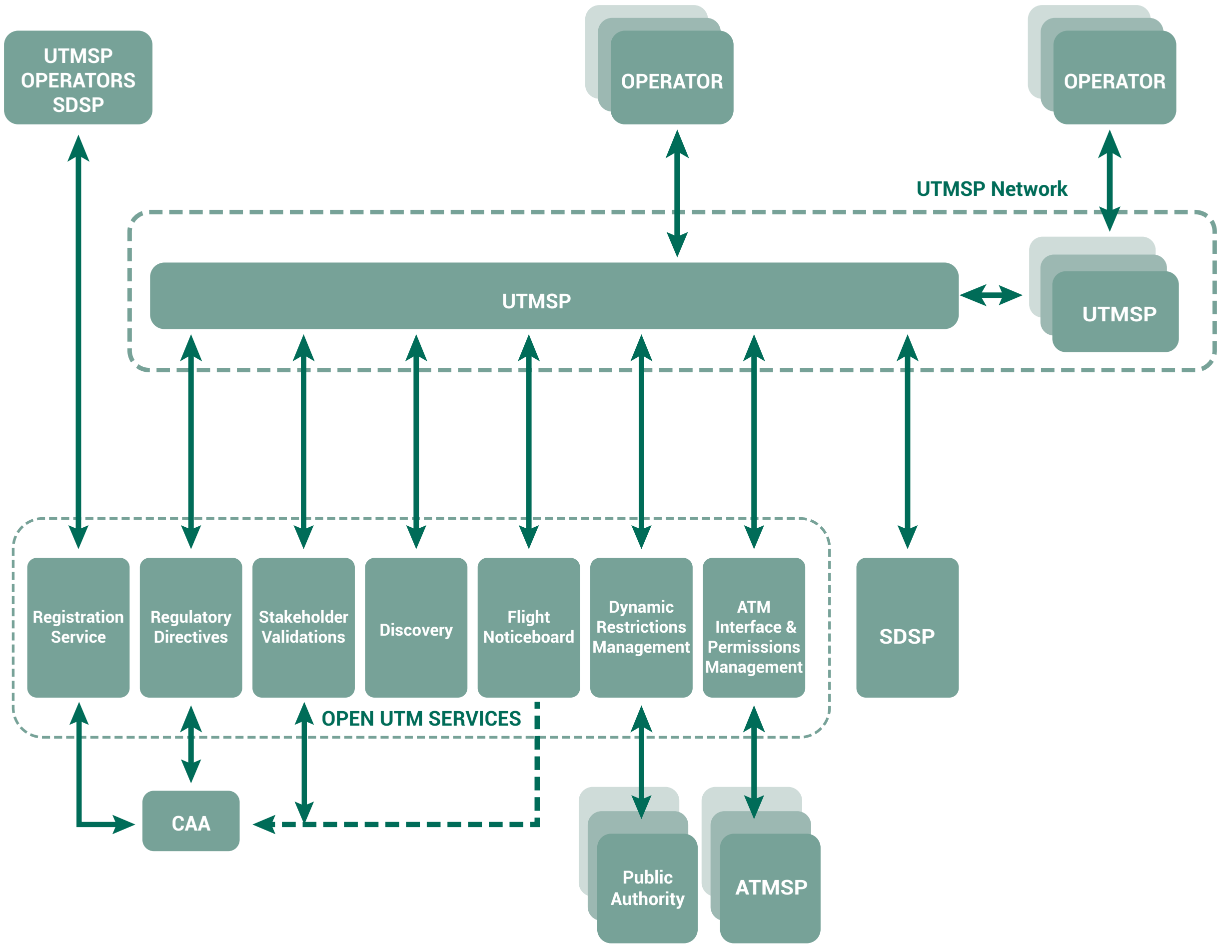


Figure 5. Semi-federated Architecture perspective

Placing the Discovery and FNB services together provides a critical enabler to UTMSPs in the course of delivering operational services. During flight planning, there is a need for an independent service to facilitate the identification of active operations based on shared flight planning data. There are probably many different solutions, one of which is the ASTM DSS mechanism (see 1.4.6.1.1). The next step is the need for additional 'flight approval' service which compares flight plans, rejects plans back to UTMSPs for further deconfliction or accepts plans. There is a little ambiguity as to whether this service should be located in the FNB or if it is verification service which checks that appropriate deconfliction has been achieved.

During the in-flight phase, the Discovery and FNB services will support identification of active UTMSPs who require notification of range of operational information. The UTMSPS will be responsible for information cascades and notifications – the system will provide UTMSPs with the data of who to contact so that UTMSPS remain responsible for the primary notifications to be sent out – on a peer-2-peer basis. The Open-UTM service has a different information notification role relating to the broader ecosystem which also needs to be considered e.g. systems or services are unavailable.

It is not necessary that all services in this architecture are created, managed, operated by the Open-UTM Service provider for example:

- ATM Interface and permissions management service could be independent service(s) however the access route is via the Open-UTM service.
- The Dynamic Restrictions Management service could be provided by the Aeronautical Information provider rather than creating a separate data management service. This needs to consider the current update cycles for Aeronautical information.

To enable communications in this approach will require creation, standardisation and management of several interfaces and service protocols – key one is the UTMSP – Open UTMSP, UTMSP-UTMSP and UTMSP-ATMSP. There are others which do not require standardisation and can be left to the market e.g. UTMSP-SDSP, Operator-UTMSP, ATM Interface-ATMSP if the service is separate from Open-UTMSP.

2.2.2 Federated Approach

The federated approach proposes that UTMSPs are responsible for service exchanges (Table 3) on a Peer-2-Peer (P2P) basis which will be enabled by the Open-UTM Services. The approach addresses the centralisation of several Open-UTM Services while maintaining a shared or common information capability for all participants and critically it provides the Regulator with access to the system and the operational data.

Changes include:

- All participants require UTMSPs to access services including Public authorities. It is assumed different categories of UTMSPs are possible to support the needs of specific authorities e.g. law enforcement, fire services etc
- UTMSPs are able to engage with airports and FRZs directly rather than through the ATM Interface. The natural progression is that UTMSPs will provide airports with a tailored service (yet to be defined from a regulatory perspective) which enables the airports to fulfil the ATMSP role).

This does not preclude one or more broader network ATM interface service e.g. a LAANC or NATS Airspace User Portal which support multiple airports and FRZs. The key is providing a basic level of service which should democratise access to UAS ecosystem for all airfields and FRZs in the UK whereas a fully federated system from day one will leave airfields and FRZs without an easy access to or means to explore new opportunities [Ref. 2].

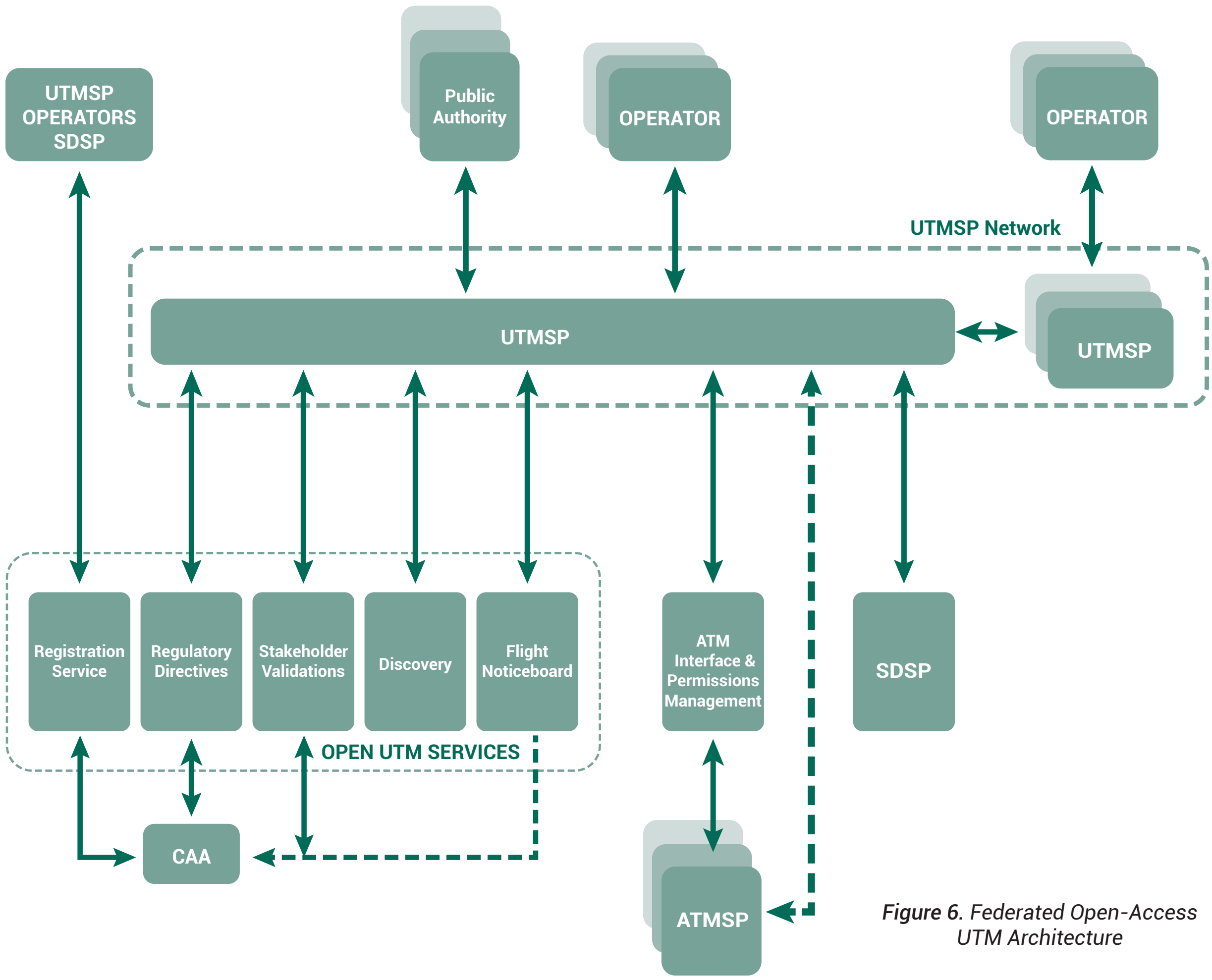


Figure 6. Federated Open-Access UTM Architecture

The key advantage of this approach is the reduction in the number of interfaces to be created by ensuring operational activities are limited to UTMSP-UTMSP which is enabled by the Open-UTM service via the Discovery-FNB services as before. One way of implementing the Discovery service is the application of the ASTM Discovery and Synchronisation Service (DSS) Standard which will enable communication between UTMSPs and support several service protocols.[10] It is a stand-alone service and can be provided by any service provider.

The Open-UTM service provider can provide DSS as part of its service agreement or it can be federated away from the Open-UTM service. By maintaining the need for general air traffic collection using the Flight Noticeboard, the CAA might prefer to separate the DSS from the Open-UTM service in order to enable other participants to deliver DSS but also to avoid conflict created by a service provider who may have access to the Flight Noticeboard. The information held by the Open- UTM services and DSS will have to be synchronised.

DIRECTION & RESEARCH AREAS	DESCRIPTION
Test & Evaluation	It is necessary to develop UTM systems, methods and conduct trials to assess the trade-offs of in the architecture, technology and operations to obtain direct evidence of how the system would work in practice.
Architectural Decisions	The CAA should review the UTM concept to address it's role and level of engagement to fulfil the oversight responsibilities including • Role of Flight noticeboard and UTM traffic data. • ATM Interface and Permissions as a means of coordinating drone operations across controlled zones.
Architectures (General)	The effect of UTM on overall safety need to be investigated.

Table 4. Archtectural research areas

[108] ASTM published the Remote-ID service standard on Dec. 11, 2019 which uses DSS. ASTM F38 UTM committee is preparing the broader DSS standard to support several key services and underlying operational concepts

3 UTM Scenarios

To aid in the development of UTM capability and then to evaluate it, the project identified an initial set of scenarios (see Table 5) which capture the broadest current and future applications for UTM. To simplify the terminology, operations are described as nominal and off- nominal i.e. normal operation affected by a disruption.

No.	DESCRIPTION	STATE
1	BVLOS and VLOS Operations in Uncontrolled Airspace and Urban Environment	Nominal
2	Emergency Situation on Ground among BVLOS and/or VLOS Operations in Controlled or Uncontrolled Airspace	Nominal; possible Off-Nominal. Emergency situation presents a potential for an Off-Nominal as a temporary flight restriction would require non-emergency responders to vacate airspace unexpectedly.
2	BVLOS Transit through Controlled Airspace (Rural -> ATM -> Urban)	Nominal as this transition would be planned during pre-flight.
3	BVLOS Operation Handover in both Controlled and Uncontrolled Airspace	Nominal as this transition would be planned during pre-flight.
5	BVLOS Operation with dynamic TFR or High-Priority Conflict in Uncontrolled Airspace	Conflict presents an Off-Nominal condition that requires detection, alerting and solution for returning to a new Nominal.

Table 5. Open-Access UTM Scenarios

These scenarios can be broken into the operational characteristics defining the airspace and the environment as shown in Table 6. The scenario and operational characteristics are used to determine the actions of UTMSPs and other actors during normal operations and problem scenarios.

DESCRIPTION		SCENARIO No.				
		1	2	3	4	5
Type	VLOS	✓	✓			
	BVLOS	✓	✓	✓	✓	✓
Environmenmt	Urban	✓	✓	✓		
	Rural		✓	✓	✓	✓
	ATM e.g. airport		✓	✓		
Airspace	Controlled		✓	✓	✓	
	Uncontrolled	✓	v	✓	✓	✓
Operator: UAS	-	1:1	1:1	1:1	1:Many	1:1

Table 6. Operational Characteristics

3.1 Nominal Operations

All operations, by definition, are nominal if their trajectory follows the flight plan defined during the pre-flight planning phase. It goes without saying that the operators will have satisfied the regulator and obtained a 'licence' which would enable operations covered by the scenarios and selected a UTMSP who can meet their requirements. Prior to initiating an operation, the operator will engage with the UTMSP's flight planning tools to develop a flight plan – these tools will comprise the latest aeronautical information, weather predictions, terrain, obstacle and air traffic data to enable the best possible pan to be created and submitted for approval. Nominal operations will be supported continuously by the E-ID, Tracking and Surveillance and Monitoring & Alerting services until the flight ends or a disruption occurs. It is assumed that support requirements are also captured by the UTMSP e.g. communications and navigation infrastructure, obstacles, weather and system health.

3.2 Off-Nominal Captial Operations

Off-Nominal Capital Operations occur due to vehicle or operator emergencies, changes in priorities for other operations, or emergencies on ground or air. Causes include degraded quality of service, loss of control, degraded environment, loss of C2 link, GNSS or situational awareness and so on – today each of these must be accounted for within the operating safety case.

CONTRIBUTOR	DESCRIPTION
Degraded Quality of Service	Degraded infrastructure or related services (GNSS, C2, UA to UA, etc.). Loss of airspace conformance.
Loss of Vehicle	Vehicle excursion from design/desired performance envelope due to system failure, loss of power, cyber-attack, bird strike or other condition.
Degraded Environment	Turbulence, convective weather, fog or unexpected precipitation can pose a hazard to the operation and must be monitored. Each of these changes over the course of any operation and the level of change and system resilience against each is key for mitigation.
Loss of C2 Link	Operator loses ability to communicate with the aircraft and/or receive telemetry updates. Mitigations can include link redundancy, route planning to maximise selected C2 bandwidth, contingency planning to re-establish link, or a combination of the above.
Unannounced Incursion of UAS Volume	Incursion by non-cooperative aircraft, high priority aircraft, temporary FRZ or vehicles in distress.
Loss of Situational Awareness	System malfunction where the operator loses situational awareness and can no longer (or under diminished capacity) continue to monitor the operating environment for off-nominal contributors.

Table 7. Examples of disruptions considered

Monitoring and alerting occur continuously during flight operations – as disruptions are encountered, various services and functions are employed to return the system to a new nominal. Detection of these disruptions progresses from awareness, contingency to emergency requiring priority actions involving initially notifying the operator only followed by notifications to the affected operations and the Open-UTM Services.

3.3 Example: Scenario – BVLOS Operation in Uncontrolled Airspace

The drone operator is, typically, the end-user of the end-to-end UTM solution and, as a result, will be the target customer for many of the new services. We previously described the operator and UTMSP perspectives in the Open-Access UTM report [Pg. 25. Ref. 2] – in these descriptions the journey was divided into three segments: the pre-flight phase, in-flight phase and post-flight phase. The intention of this section is to illustrate how services, functions and data-exchanges enable the flight operation from planning to termination.

3.3.1 Pre-Flight Phase

In this scenario, the operator is assumed to have the appropriate permissions to operate drones and has obtained the necessary operator and aircraft registrations which are needed to subscribe with an approved UTMSP. From the perspective of the drone operator, the pre-flight stage primarily involves the development of a proposed flight plan that can be submitted to and validated by the UTMSP. The validation exercise may require the drone operator to revise the proposed flight plan to appropriately deconflict with other airspace users and other issues that the UTMSP may anticipate.

Figure 7 illustrates the flight approval process in which the operator uses UTMSP tools to prepare a flight plan which is submitted by the UTMSP to the Open-UTM service for deconfliction and approval. Note that the Operator-UTMSP and the UTMSP-SDSP interactions are independent of architecture therefore the top part of the figure is the same for the two architectures considered in this report. The UTMSP-UTMSP interaction as facilitated by the Open-UTM service is dependent on architecture – these are both shown in Figure 7.

The proposed flight plan indicates the volume of airspace within which the drone operation is expected to occur, the corresponding time and duration of the operation, and potentially any additional information/locations of key operational events such as the launch and recovery and emergency landing locations of the planned operation. A digital flight operation can be defined by a series of 4D volumes around the selected trajectory together with the constraints of terrain, obstacles and other aircraft users.

There are multiple geographical regions specific to an operational plan: flight geographies, conformance geographies, and protected geographies[11]. Each of these defined geographical regions has specific meaning within the UTM software – see Figure 8.

- **Flight Geography** – Created and submitted by the operator using the flight planning tools. It describes the physical location of the planned operation.
- **Conformance Volume** – The flight planning tool will add a buffer to the flight geography. The operation is always intended to stay within this conformance geography – any violation will give result in an alert perhaps a notification depending on severity. There is exactly one conformance boundary per flight geography. If a drone violates the set boundary, it is flagged as non-conforming and the UTM software will notify the operator who must take immediate action. Further violations or lack of action will convert the flight to an off-nominal operation.
- **Protected / Operational Volume** – The flight planning tool will add another buffer and computes the Protected boundaries which is used for deconfliction operations and other constraints in the system. The protected geography that drives acceptance "flight plan approval" or rejection of an operational plan.

[11] Proposed volumes to be represented in WGS84 coordinate system – GPS also uses this as its reference coordinate system

Flight Approval Process

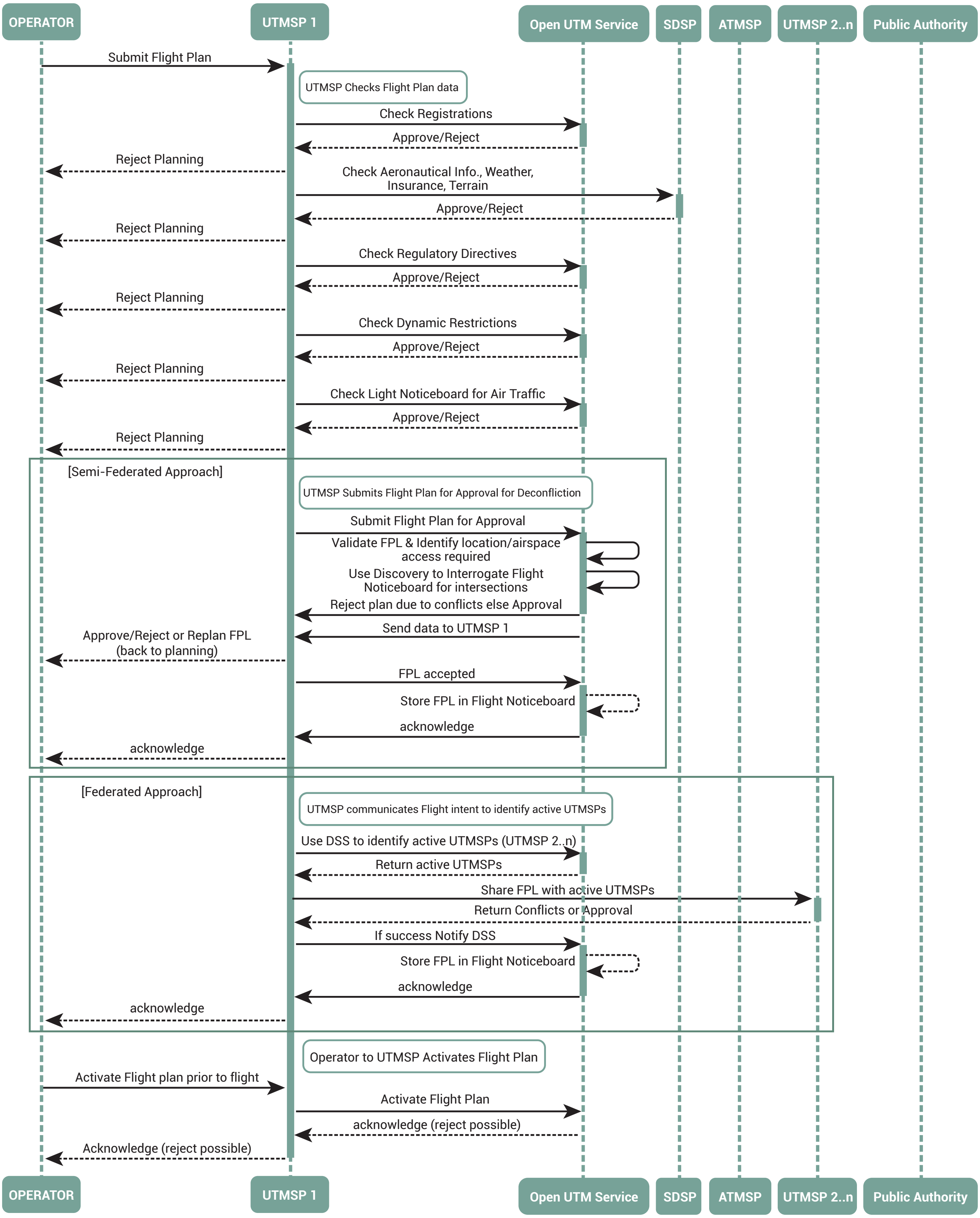


Figure 7. Pre-flight Approval Sequence for operation in uncontrolled airspace

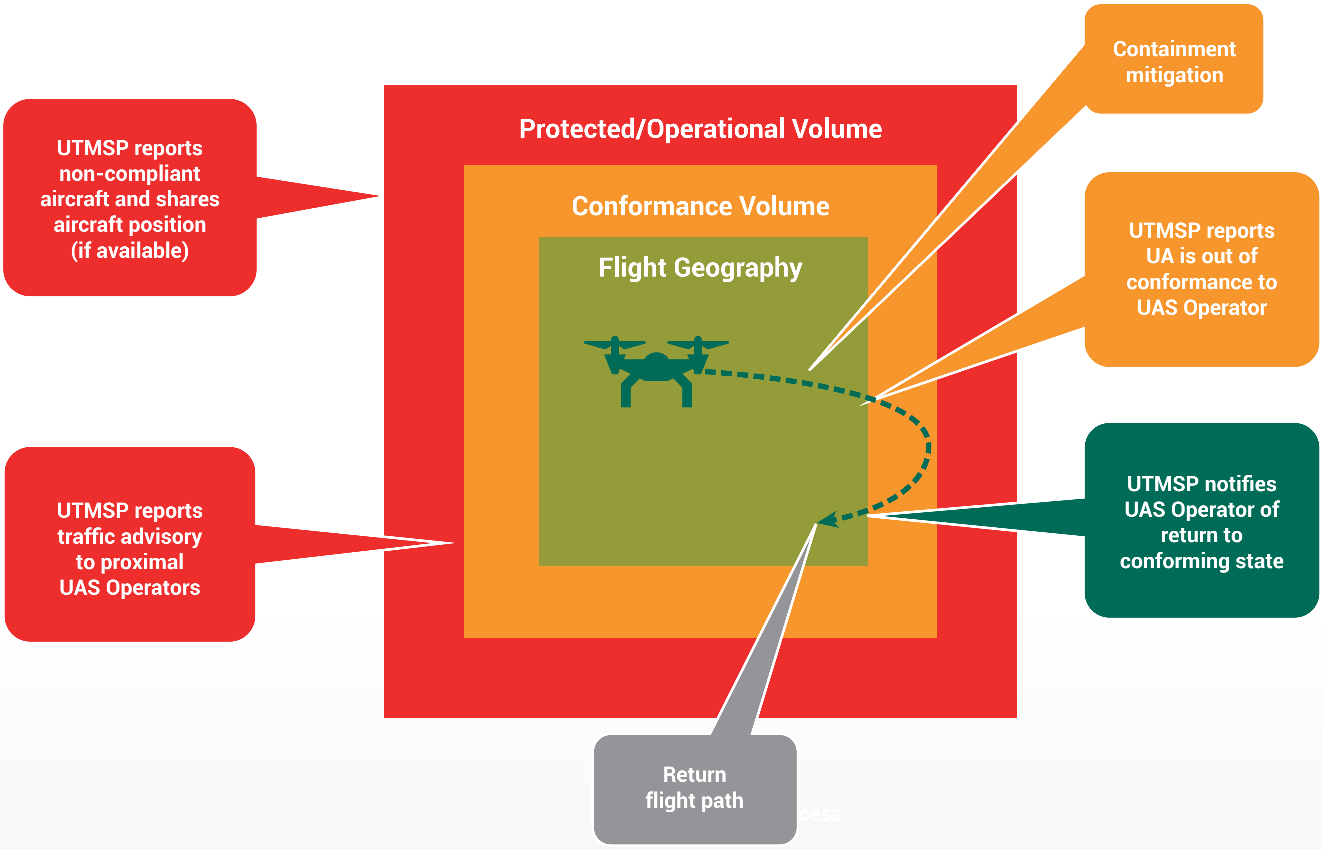


Figure 8. Operational volume geography

There are two major responsibilities of the UTMSP during the in-flight phase of the drone operation:

1. Drone Conformance monitoring – monitoring the drone's operations and performance to ensure it conforms to the operator's accepted flight plan and subsequently notifying adjacent airspace users in the case of non-conformance.
2. Monitoring airspace activities through the engagement with the Open UTM Services and other UTMSPs and subsequently notifying the drone operator in the case of disruptions.

Monitoring airspace activities through the Open UTM Services is a major necessity that is expected to be required of UTMSPs by the regulator to be recognised as an "authorised" provider. There is continuous engagement with other UTMSPS and the Open UTM Services to monitor airspace states and activities. The rate at which data is refreshed across the UTM network during this in-flight phase should be considered to be as high as is reasonably possible, allowing disruptions to be managed using near real-time data. During nominal operations, the UTMSP is expected to provide E-ID, Tracking and Surveillance and Monitoring & Alerting services until the flight ends or a disruption detected. Following a disruption, other UTM services are engaged such as the dynamic re-route in order to enable the completion of the operation.

Monitoring and Alert

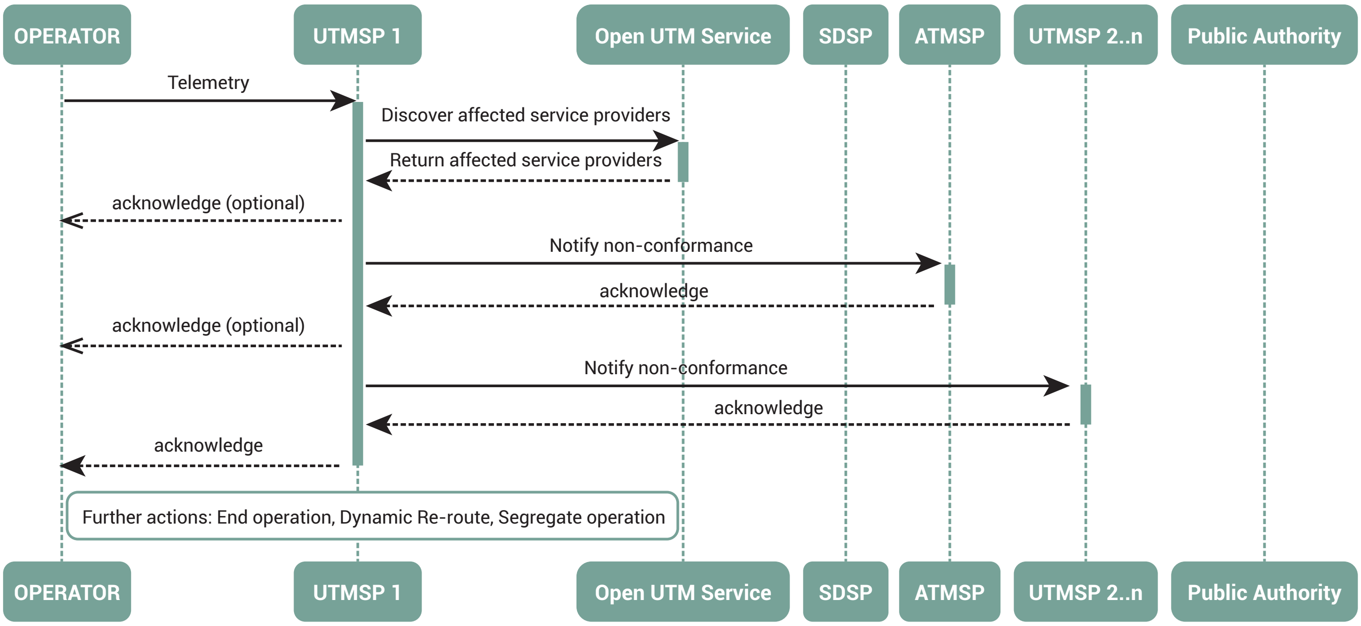


Figure 9. Monitoring and alert services

As an example, Figure 9 illustrates the Monitoring and Alert services – the UTMSP, using drone telemetry data in the UTM software, will monitor the performance of the operation and alert the client and other airspace users when off-nominal or off-plan conditions are detected. In addition to the UTMSP actions, the other primary participants also have a role in support of in-flight monitoring as shown in Table 8.

PARTICIPANT	ACTION	DATA
UAS	Monitors & broadcasts – C2 & navigation status – Control margins – Vehicle health	Basic and custom per UAV
UTMSP	Monitor network health – Monitor & notify – Plan violations – Weather and mapping – Traffic – Emergency notifications	Per link health data Standard data-exchange
Other UTMSP	Notification of disruptions – Flight violations – Emergencies	Standard data-exchanges per data type
SDSP	Monitors and broadcasts – Weather updates – Navigation and communications infrastructure & coverage – Ground risks	Standard data-exchanges per data type
ATMSP	Publishes operations to FNB – New higher priority manned a/c operation e.g. Emergency Medical flight	Standard for Dynamic restriction

Table 8. In-flight Monitoring Actions of Other UTM Participants

3.3.3 Post-Flight Phase

The responsibilities of the UTMSP post-flight are centred around determining the state of the flight termination and communicating this state with relevant stakeholders. In nominal conditions, the operation will conclude as planned. Otherwise, the UTMSP must engage the drone operator and/or interrogate the received telemetry to determine if the flight has been terminated as expected. In unscheduled/unexpected flight terminations, the UTMSP may directly inform local authorities and/or the regulator as required.

The UTMSP will monitor the performance of the operation and alert the client and other airspace users when off-nominal or off-plan conditions are detected

4 Communication Requirements

The objective was to define the high-level communication requirements for service provider IT systems to be able to communicate with each other effectively. The three integration items to be solved are the physical integration using interface definitions and message protocols, functional integration provided by the architecture to enable UTMSPs to integrate with ease and semantic integration to ensure that systems are able to use and interpret the data. These integration challenges will need to be addressed by developing a communications framework based on Open standards, systems interoperability and data consistency.

4.1 Open Standards

Open-Access UTM is strategically aligned with the Government's ambition to capitalise on the opportunities around Open Standards [Ref. 5] and Transformation Strategy [Ref. 9] that allow for systems to be interoperable through the adoption of Technology Code of Practice (TCoP) [Ref. 10]. The TCoP is a set of criteria to help government design, build and buy technology and is meant to inform, guide and align with Government requirements.

The Government has defined the following principles for IT services:

- Collaboration between all interested parties, not just individual suppliers.
- A transparent and published decision-making process that is reviewed by subject matter experts.
- A transparent and published feedback and ratification process to ensure quality.

4.2 Interoperability

Today, UTM and UAS technologies are highly fragmented due to the emergent nature of many of the involved technologies. UTM is still in development, platforms are highly bespoke and connectivity approaches are still evolving while information will have to be shared between many systems; Operators will create and submit flight plans and share telemetry from their drones, UTMSPs will subscribe to aeronautical information and create notifications, drone telemetry may be shared with multiple systems including V2V and so on. There is a need to build consensus on interoperability to achieve seamless, safety-critical and real time data-exchanges between stakeholder systems.

Technical interoperability is the ability of hardware, software components, systems and platforms to communicate seamlessly. Achieving it requires adoption of common communication protocols and supporting infrastructure for the protocols to operate effectively.

It is important to develop open standards and open API definitions as part of a framework of specification(s) whose data and functions are made visible to interested community. The approach should be evidence-led i.e. use data and learnings from trials and evaluations. Today there are a number of approaches that are in development such as the System-Wide Information Management (SWIM) framework and ASTM's UTM activities.

4.3 Security Considerations

There is a general consensus on the security requirements needed to support communications. These can be traced to the ISO/IEC 27001:2013 and NIST SP 800-53. A key application is the creation and exchange of electronic data e.g flight plans.

- **Identification & Authentication:** Verifying the identity of a stakeholder IT system, using a standardised authentication method (e.g. token), before data can be exchanged or access to information given.
- **Authorisation:** Depending on the type of stakeholder, the regulatory approval will determine their rights and capabilities within UTM. IT systems will be required to grant access based on the regulatory approvals.

- **Data Integrity:** Data flows within the system should be protected from unauthorised modification.
- **Confidentiality:** All approved systems and processes need to ensure that information is not accessible or disclosed to unauthorised parties or systems.
- **Data protection:** Systems will be required to maintain the integrity and confidentiality of information.
- **Records:** Each stakeholder will be required to maintain records of system activity and ensure that critical events (security-related, safety-related) are recorded for analysis and audit.
- **Reliability:** This requirement is focussed on ensuring traffic services remain available, fault tolerant and recoverable. There may be a fail-safe requirement to be applied to the different traffic services.

4.4 Points of Reference

There is a need to standardise how data is communicated between stakeholder IT systems, the vocabulary and information to be used and shared between stakeholder IT systems. There are 2 points of reference for communication interfaces and data-exchanges models that provide a starting point for Open-Access UTM namely, Eurocontrol's SWIM and ASTM's UTM standards.

4.4.1 System-Wide Information Management (SWIM)

The international community, through ICAO and in Europe, Eurocontrol, has been developing the SWIM concept for over a decade as part of ATM modernisation as a means to provide a systematic, global approach for digitally managing, accessing and exchanging ATM information. The concept consists of standards, infrastructure and governance for the exchange and management of air traffic information between approved parties and IT systems. SWIM data concepts have been used in the NASA UTM and SESAR U-Space research projects as well as by dozens of UTM software developers to research UTM communications and information exchange.

4.4.1.1 Technical Interoperability

A number of technical specifications (called Profiles) for standardising communications between system participants have been developed in support of the SWIM concept. There are three profile definitions Yellow, Blue and Purple corresponding to non-real time data exchanges, real-time data exchanges and non-real time exchanges in low bandwidth conditions. The components of the communications infrastructure between two or more IT systems using the internet have been developed and defined using Open-standard web services protocols including SOAP, REST, AMQP and security features for interfaces and messages.

The Yellow profile is most mature and defines a set of requirements for interface protocols and IT infrastructure that can help with the development of UTM data-models.

4.4.1.2 Information Exchange Models (IXM)

1. **Flight data** – The Flight Information Exchange Model (FIXM Ref. 17) is designed for representing flight information with the latest update, FIXM 4.2 (released in December 2019) designed to support flight planning in a collaborative environment. It lacks support for UTM and requires extension and modification to capture information such as, flight status (planned, filed, completed), operation type (VLOS, BVLOS, etc)
2. **Aeronautical Information (AI)** – AIXM [Ref. 18] is the data standard for ATM. It can express complex geometric objects and their relationships to each other. It was created more than a decade ago, and many authoritative AIP providers are currently in progress or have already started producing their regular AI updates in AIXM. In the UK, DfT and NATS investigated and then implemented the use of AIXM for Flight Restriction Zones [Ref. 19] around UK airports.

   While AIXM is already standardised and extensible, it does not currently fully implement the requirements of UTM. There is a growing interest in the expression of AI data using GeoJSON, an alternative, less verbose data format – EUROCAE have published a draft standard for Geofencing using GeoJSON (see 4.4.3).

3. **NOTAM** – The Digital NOTAM [Ref. 18] format is part of the AIXM standard and has the same capability to express complex geometric objects. Temporary Flight Restrictions and other UTM relevant information can already be expressed in the DNOTAM format, and there should be little additional work to utilise this format for other UTM use cases.
4. **Weather** – It was discovered that although standards such as the Weather Information Exchange Models (WXXM and IWXXM) exist in ATM for the expression of weather forecasts or reports, they are significantly insufficient for the expression of hyper-local weather as required by UTM. There are no clear current or developing standards for this type of hyper-local information, and there is insufficient information available currently to decide on a specific standard.
5. **Surveillance** – The ASTERIX (All Purpose Structured Eurocontrol Surveillance Information Exchange) [Ref.21] standard has been in wide use for exchanging surveillance data across the aviation community. It uses a binary approach for the data to enable its use when the communication bandwidth is limited.

4.4.1.3 SWIM Reference Information Model
Currently, the SWIM ecosystem is designed for the ATM domain therefore does not support UTM. Various SESAR research projects are leveraging SWIM concepts but the results are yet unavailable.

4.4.2 ASTM Approach
The ASTM F38 UTM Committee was created to build industry consensus on UTM with a view to converting this into standards. The standards activities build on a distributed UTM architecture together with learnings from the NASA and FAA UTM trials programme.

4.4.2.1 Technical Interoperability
The committee is working on a decentralised approach in which the UTMSP is responsible for delivering majority of UTM services on a peer-2-peer basis. The necessary peer-2-peer collaborations are to be achieved using the Discovery and Synchronisation Service (DSS).

4.4.2.2 Information Exchange Models
ASTM is creating service specific standards which all use the communication requirements for DSS. The committee is working on multiple standards but has only released the Remote-ID standard [Ref. 23]. The data models are bespoke but take advantage of vocabulary from the SWIM standards discussed previously.

4.4.2.3 Common Information Model
The Committee is in putting together an information model or Common Data Dictionary to capture data types, formats and the message catalogue. This has yet to be published.

4.4.3 EUROCAE

EUROCAE has set-up UTM working groups to work on standards in the UTM domain. Currently their work is limited to standards on the U-Space Geo-fencing and Electronic identification services. The committee recently conducted a consultation on a Geo-fencing draft standard ED-269 "***Minimum Operational Performance Standard for UAS Geo-Fencing***". The standard addresses the geo-awareness (alerting) function for operations of drones in the Open Category as stated by EU regulations – in essence drones do not enter excluded areas of the airspace.

RESEARCH AREAS	DESCRIPTION
Communication and Data standards	The following UTM related items should be addressed; Interoperability standards, data exchange protocols, requirements for new data e.g. very low-level airspace and terrain and digital processes.
Cyber Challenge	UTM will depend upon a wide range of point-to-point data exchanges and it will be necessary to allocate an appropriate degree of resistance/resilience and understand the consequence. It will also be necessary to understand how this can align with wider state level security concerns.
Services framework	As many of the UTM capabilities (service automation) are outside of the main aviation system there is need to consider how these fit the regulatory model.

Table 9. Communication infrastructure research areas

5 Regulatory Considerations

A key role of the CAA is to ensure that the aviation industry meets the highest technical and operational safety standards together with furthering the interests of stakeholders and the public by considering parameters such as cost, quality and availability.

It achieves these by ensuring competence of service providers, periodic audit and evaluation and approval of designs. To help the community navigate through the spectrum of requirements, the CAA publishes the Civil Aviation Publications (CAPS) which are based on national and regional (EU) legislation and global standards and recommended practices as agreed at ICAO.

5.1 General Duty

The CAA has a general duty to protect the public and consumers of aviation services. This duty is discharged through four regulatory areas – Safety, Economic, Airspace and Consumer protection. Each group takes a specific viewpoint about the aircraft, traffic services, service providers, operations and consumers of UTM – operators and end-users of drone services.

The regulatory activity includes:

- Participant approvals together with regulator reviews of training, experience, procedures and working practices as given in the entity's quality management system.
- Periodic audit to ensure compliance with approvals and regulatory framework.

Key attributes to regulations are proportionality, operation-centric, performance-based which have to be applied to UTM, service providers, vehicles, IT infrastructure and automation.

5.2 CAA Guidance

The CAA publishes guidance material in the form of Civil Aviation Publications (CAPS) which are based upon national and EU legislation and best practice, such as ICAO Standards and Recommended Practises. They are published in order to provide guidance and details of any additional national requirements.

The CAA has published its perspective on UTM in CAP 1868 [Ref. 3] in which it recognises the importance of building UTM using existing rules and policies but also bridging the gaps where necessary with new or alternate policies. Crucially, the document lays out the CAA's legal duties in the context of maintaining safety in aviation and identifies airspace design and electronic conspicuity to be critical for UTM.

5.3 Automation

Automation is the key enabler of a future UTM system to ensure a safer, cost-effective and robust traffic management system. It will replace the role of the human operator with individual services which can be combined to support a spectrum of UAS operations. In such a system, the role of human operator, managers or regulators are elevated to decision-making and providing oversight. To create the underlying IT infrastructure and supporting software means accessing skills and expertise outside traditional aviation which provides an opportunity for truly cross-cutting innovation.

All of this presents a number of regulatory challenges that need addressing.

- Introduction of automated traffic services requires careful consideration of safety particularly as service interactions increase and introduce complexity into the system.
- An automated system will still require human-technology integration to account for certain interactions e.g. controlled airspace operations.
- UTM has key points of reference which require regulatory attention e.g. use of geo-fence, electronic conspicuity, service logic and standard,
- UTM will be built on modern IT capabilities and connectivity to create a data-enriched environment which provides greater opportunity to collaborate and share data to provide value-added services. However, data usage will need to be regulated to ensure fair and transparent use.

5.4 Service Provider

UTM services and UTM service providers are not captured by the current regulatory system – therefore there is a need to consider how these may be brought into the regulatory model – to assure both accountabilities for the delivery of services as well as to ensure appropriate confidence in the overall operational service robustness. In order to achieve this, the industry and CAA should work together to propose ways of enabling access to services such as the registration, licensing, approvals information and validation processes.

5.5 Non-Cooperative UAS

There may be many reasons for non-cooperative use of drones in the UTM environment. There will be a need for information and education about the role of UTM in the national airspace – this should focus on building confidence about the benefits of participation for legitimate users such as improved situational awareness.

Illegal and criminal use of drones in a UTM environment will require legislation for enforcement and to ensure minimum product standards are followed – including operator and drone registration combined with electronic identification. The aviation community also relies on users to self-police and report negligent behaviour or wrongdoing where safety maybe compromised. In other situations, the appropriate way forward is a technology solution e.g. airports where there is a need for an early-warning system to provide confidence to users and operators. Finally, the UTM community should investigate how the UTM system can identify and locate uncooperative drones and the operator.

5.6 Environmental Protection

Wide-spread use of drones below 400ft will bring with it the issue of noise. In the industrial settings, drone operations will increase the noise levels leading to greater exposure while in rural and urban settings UAS operations will create a nuisance at the least with the potential of wide-spread community rejection. Currently there is no activity investigating the science of UAS noise, noise reduction and operational mitigations. The way forward should be to investigate noise reduction and exploring a range of restrictions e.g. designated routes and restricted areas or red-zones which can be enabled using UTM.

6 Way Forward

The government and industry are committed to maintaining a safe national airspace to which all users, including the unmanned aircraft community, are able to have routine, fair and equitable access. UTM addresses many of the airspace integration requirements for drone operations therefore it requires a coordinated approach across the UTM and UAS stakeholder community to deliver an ecosystem that will ultimately enable the industry to capitalise on the market opportunities presented by drones.

In support of these goals, the Future Flight Challenge[12] is focussed on unmanned industry's ambition to develop UK's unmanned aviation technologies, services in support of an ecosystem that will enable safe, routine and sustainable services. Clearly, the FFC challenge provides a much-needed boost for the vibrant and innovative UAS industry in the UK and crucially requires that projects should consider the whole integration picture. This will include addressing how UTM facilitates many of the traffic management functions described earlier including cooperation between UTM service providers. Adopting the Open-Access UTM Framework as the starting point for UTM initiatives, will enable a level of coordination across the many different projects that Future Flight will ultimately fund.

There is also a need for the community to come together around a common vision for success. With UTM, the aviation industry can collaboratively deliver safer drone operations in different sectors and assure routine operations. Thus, one view of success is the accelerated adoption of commercial drone services enabled by UTM.

Roadmap

A UK UTM roadmap will provide clarity and direction about how UTM can support and unlock commercial UAS operations together with the opportunities available in the development of UTM. A user-focussed and market requirements approach will ensure that the roadmap captures relevant applications and broadest use of UTM to enable the roadmap to cross-cut across the industry. The roadmap will require regular review to ensure it captures progress and updates such that it remains relevant for industry and government.

CPC in partnership with DfT, the CAA and industry has started activity on gathering data from industry participants in terms of the market opportunities, identification of UTM requirements and the regulatory impact necessary to enable the opportunities. This work will be progressed over the next year.

- **Industry** – address the Market drivers (service requirements, access to technology, acquisition cost & savings) when scaling-up or creating UAS services, to navigate the value chain and develop business opportunities.
- **BEIS's Drone Industry Action Group** is a Cross-community partnership (DfT, BEIS, CAA and Industry) that should consider UTM and the roadmap as it looks create greater commercial awareness of UAS services.
- **Government** – explore how the Aviation Strategy together with the AMS roadmap can facilitate the UTM roadmap. DfT's UTM Policy group to review the roadmap, the gaps and consider how it can address the issues raised.
- **Regulator** – The CAA Innovation Hub will introduce a series of UTM Sandbox calls (technology, services, operations) to test hypotheses for a UTM technologies in its considerations for a regulatory framework.

[12] Future Flight *https://www.ukri.org/innovation/industrial-strategy-challenge-fund/future-flight1/*

Cooperation

As the technologies and applications evolve rapidly, there is a need for greater cooperation between the UAS/UTM community, the regulator and the government to work together to capture learnings across regulatory, technological, operational and critically the economic challenges facing large-scale deployment of UAS services. There is an opportunity for the different forums in the UK to engage with the UTM roadmap to help overcome barriers and explore technological solutions through trials and inform/gather sector specific data.

- CAA – With the UK exiting the EU and EASA, the CAA should consider ways in which to advance UTM research and development in partnership with UK industry.
- Standards bodies need to develop consensus on the basic principles of UTM – As the UK looks to the future, there is a need to develop consensus on UTM across standards bodies.
- Future Flight Challenge Fund's advisory committee has a broad advisory group and can drive progress on UTM through funding projects that tackle the operational and technology challenges.
- Member universities of the UK Aerospace Research Consortium are already active in the UAS space and should partner with industry to bridge the technology gaps across the UAS industry.
- Pathfinder Programme is currently focussed on BVLOS challenges. The programme should consider including UTM-roadmap to help it evolve the BVLOS landscape and identify new Pathfinder projects which are developing solutions with UTM as a key component.

Policy and Regulatory Environment

DfT has a key role in setting the UAS/Airspace agenda – as demonstrated by the policy actions on drones, the Aviation Strategy, Airspace Modernisation, Open-Access UTM and the UTM Policy group. Crucially, DfT can provide a single vision for bringing together initiatives on UAS, UTM and airspace integration.

The CAA's Innovation Hub has created a proactive environment for UAS/UTM innovation creating new ways of learning through a 'Sandbox' model. These learnings should be disseminated to the industry to enable best practise to be used directly particularly over the next year during which Future Flight Challenge will result in the CAA being inundated with permissions requests.

The CAA and DfT jointly lead on the Airspace Modernisation Strategy, a plan up to 2040 which is aimed at addressing the structural and technological barriers for UK airspace. The current AMS work package does not explicitly include UTM perhaps due to the lack of maturity and objective evidence demonstrating its impact on airspace, users and technology.

- Airspace Modernisation Strategy should explore via the UTM policy Group how it can engage with UTM.
- DfT's UTM Policy Group should lead on monitoring and addressing the UTM roadmap and work with the AMS programme.
- CAA Innovation Hub intends to create UTM sandbox calls and should continue publishing guidance and best practise for UAS initiatives to build e.g. UTM position paper [3] and BVLOS operations [13].
- EASA U-Space regulation – There is a need to address the draft EASA U-Space regulatory framework to determine direction and guidance for UTM in the UK.

Research Needs

This programme identified areas of research in the body of this report. *The following captures broader aspects of UTM.*

- Electronic Conspicuity is critical to enabling UTM. Research into both broadcast and network identification solutions is required to address the different EC use-cases.
- Initiate research into how UTM concepts can be expanded to capture the integration of larger unmanned aircraft, higher altitudes and in mixed traffic areas.
- Development of UTM Standards for interoperability including building consensus on the performance requirements for systems infrastructure and cyber-security to provide appropriate degree of resilience and robustness.
- Investigate the safety requirements associated with automated traffic management systems connecting multiple ground-based and airborne systems.
- Research the use of deep analytics and machine-learning applied to predictive traffic management.
- Targeted UTM trials and technology development aimed at stress-testing concepts and reducing risk.

Test & Evaluation

The next step for Open-Access UTM is to conduct systematic trials to de-risk and validate concepts and technologies. To assist in this, a high-level trials plan (Figure 10) was created by the UTM consortium which outlined the steps needed in order to trials UTM.

Crucially, CPC intends to field a trials programme in 2020/2021 with the following goals:

- Develop the basics of the Open-Access UTM system and services necessary to support an initial UTM trial.
- Multi-UTMSPs to demonstrate interoperability and data-exchange using Open-UTM services.
- Incremental evaluation of use-cases in normal and emergency scenarios to stress test the operational procedures and UTM services.
- Publish learnings from trials in particular the Open-Access UTM data to use in other initiatives e.g. Future Flight projects.

Incremental Capability

Planning > Systems & Interface Definitions > Simulations > Trials > Analysis > Dissemination

INITIAL UTM

- VLOS – BVLOS
- Wide Area & Linear Ops
- Services
- Open UTM-Service
- Pre-flight Planning
- Electronic Identification
- UAS Air Traffic
- Tracking

CONTROLLED AIRSPACE

- Operations, Entry, Transit
- Airfield & FRZ
- Services
- ATM Permissions
- Automation
- Intersecting Operations
- Deconfliction Procedures
- Dynamic Restrictions

NON-SEGREGATED AIRSPACE

- Rural and Urban BVLOS
- Services
- Tactical Deconfliction
- Audit

Figure 10. UTM Test and evaluation

7 References

1. UK Aviation Strategy 2050 – ***https://www.gov.uk/government/consultations/aviation-2050-the-future-of-uk-aviation***

2. Towards a UTM System for the UK, Oct 2019. ***https://cp.catapult.org.uk/2019/09/30/new-report-points-way-to-shared-airspace-between-drones-and-traditional-aircraft/***

3. CAP 1868 A Unified Approach to the Introduction of UAS Traffic Management. Dec 2019

4. High-level regulatory framework for U-space. 13-03-2020 ***https://www.easa.europa.eu/document-library/opinions/opinion-012020 https://www.easa.europa.eu/sites/default/files/dfu/Opinion%20No%2001-2020.pdf***

5. NASA UAS Traffic Management ConOps v2.0. March 2020. ***https://utm.arc.nasa.gov/docs/2020-03-FAA-NextGen-UTM_ConOps_v2.pdf***

6. UTM Strategic Deconfliction Final Report, 2018. ***https://utm.arc.nasa.gov/docs/2018-UTM-Strategic-Deconfliction-Final-Report.pdf***

7. U-Space Gulf of Finland Project – ***https://www.sesarju.eu/node/3387*** and ***https://www.sesarju.eu/sites/default/files/documents/projects/SESAR%202020%20GOF%20USPACE%20-%20Summary%20-%20Design%20And%20Architecture.pdf***

8. Open Standards Principles ***https://www.gov.uk/government/publications/open-standards-principles/open-standards-principles***

9. Government Transformation Strategy ***https://www.gov.uk/government/publications/government-transformation-strategy-2017-to-2020/government-transformation-strategy***

10. Technology Code of Practice ***https://www.gov.uk/government/publications/technology-code-of-practice/technology-code-of-practice-related-guidance***

11. Open-Access UTM Capability Development January 2020.

12. SWIM – ***https://www.eurocontrol.int/concept/system-wide-information-management***

13. CAP1827 Beyond Visual Line of Sight (BVLOS) operations of unmanned aircraft systems (UAS) in unsegregated airspace. UK CAA, Aug 2019.

14. CAA SkyWise information service ***https://www.caa.co.uk/Our-work/CAA-SkyWise/***

15. Information technology — Security techniques — Information security management systems — Requirements, ISO/IEC 27001:2013

16. Security and Privacy Controls for Federal Information Systems and Organizations, NIST SP 800-53 Rev 4. 2013

17. Flight Information Exchange Model (FIXM). https://Fixm.aero

18. Aeronautical Information Exchange Model (AIXM). ***https://Aixm.aero***

19. Project Chatham – Taking Flight: The Future of Drones in the UK

20. Weather Information Exchange Model (WXXM). ***https://Wxxm.aero***

21. ASTERIX – All-purpose structured EUROCONTROL surveillance information exchange. ***https://www.eurocontrol.int/asterix***

22. Convention on International Civil Aviation, Doc 7300/9. 2006

23. F3411-19 Standard Specification for Remote ID and Tracking. ***https://www.astm.org/Standards/F3411.htm ASTM. 11 Dec 2019***

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ORGANISATION	DESCRIPTION
	The new Connected Places Catapult accelerates smarter living and travelling in and between the places of tomorrow. CPC focuses on growing businesses with innovations in mobility services and the built environment that enable new levels of physical, digital and social connectedness. The CPC operates at the intersection between public and private sectors and between local government and transport authorities.
	Altitude Angel is an aviation technology company who creates global-scale solutions that enable the safe integration and use of fully autonomous UASs into global airspace. Altitude Angel have developed a purpose-built cloud platform that supports both U-Space and UTM, and delivers market-leading services to UAS Operators, manufacturers and software developers. In this project, the primary role of Altitude Angel is to support the development UTM regulatory framework.
	ANRA provides a low-cost cloud-based platform used for enabling sensor data acquisition, dissemination, simultaneous ground/air command and control functionality as well as communications for line of sight (LOS) and BLOS operations. ANRA has taken part in multiple R&D campaigns to test BVLOS and Line-Of-Sight (LOS) UTM operations and concepts at various test locations around the USA and internationally service provider.
	AiRXOS, a wholly owned GE venture specialises in unmanned air systems and UTM systems. Its mission is accelerating the safe, efficient, and scalable growth of unmanned vehicles, delivering services and solutions for UTM. The company supports municipalities, regional aviation authorities and private sector operators to manage and meet the increasing demand for sophisticated and safe UAS operations.
	NATS Holdings, formerly National Air Traffic Services and commonly referred to as NATS, is the main Air Navigation Service Provider in the United Kingdom. It inherited the traditions of UK air traffic control, which (founded over Croydon Airport) was the world's first air traffic control regime. NATS is involved in both ATM and UTM research projects nationally and in Europe.
	Snowflake Software accelerates innovation in the aviation industry by making the world's aviation data accessible and easy to use. Our award-winning Laminar Data Platform is the world's first commercial platform dedicated to cleaning, fusing, and organising the world's aviation data to make it easy for our customers to build valuable, operational applications.
	Thales has been delivering Air Traffic Management solutions for nearly half a century with ATC automation systems operating in over 130 ATC control centres and Thales surveillance and navigation systems deployed to over 8,000 sites globally. Thales is participating in regional initiatives (such as SESAR and NextGen).

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