Use Cases & Scenarios

SESAR Engage KTN – Safe Drone Flight

Version 3.0

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1. Glossary & Terms

1.1. Acronyms

Acronym	Definition
ACAS	Airborne Collision Avoidance Systems
ADS-B	Automatic Dependent Surveillance-Broadcast
AF	Audio Frequency
ANSP	Aeronautical Navigation Service Provider
ATM	Air Traffic Management
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer ['Controller']
ATS	Air Traffic Service
ATZ	Aerodrome Traffic Zone
BVLOS	Beyond Visual Line Of Sight
CAS	Calibrated Airspeed
CAT	Civil Air Transport
CFIT	Controlled Flight Into or towards Terrain hazard
CPC	Connected Places Catapult
CTA	Control Area
CTR	Controlled Traffic Region
C2	Command and Control
DAA	Detect And Avoid
DDoS	Distributed DoS
DoS	Denial of Service
EC	Electronic Conspicuity
ETA	Expected Time of Arrival
EVLOS	Extended Visual Line Of Sight
EVTOL	Electric Vertical Take Off and Landing
FCU	Flight Calibration Unit
FIMS	Flight Information Management System
FIS	Fight Information Service
FISO	FISO Officer
FMS	Flight Management System
FPV	First-Person View
GA	General Aviation
GCS	Ground Control Station
GPS	Global Positioning System
HAPS	High Altitude Pseudo-Satellite
HF	High Frequency
IAS	Indicated Airspeed
ICMP	Internet Control Message Protocol
ICT	Information and Communications Technology
IFR	Instrument Flight Rules

KTN	Knowledge Transfer Network
LALT	Low Altitude Operations hazard
LOC-I	Loss Of Control – Inflight hazard
LVLOS	Loss of VLOS
MAC	Mid-air Collision hazard
MCP	Mode Control Panel
OFCOM	Office of Communications
OU	The Open University
PAV	Personal Air Vehicle
PKI	Public Key Infrastructure
PO	Police Officer
PSR	Primary Surveillance Radar
RPAS	Remotely Piloted Aircraft System
SA	Situational Awareness
SEC	Security hazard
SESAR	Single European Sky ATM Research
SNR	Signal to Noise Ratio
SSR	Secondary Surveillance Radar
SVFR	Special VFR
SYN	Synchronise
TAS	True Airspeed
TOC	Top Of Climb
TOD	Top Of Descent
TI	Traffic Information
UA	Uncrewed Aircraft
UAM	Urban Air Mobility
UAS	Uncrewed Aircraft Systems
UDP	User Datagram Protocol
USS	UAS Service Supplier
USSP	U-Space Service Provider
USV	Uncrewed Surface Vehicle
UTM	UAS Traffic Management
VFR	Visual Flight Rules
VHF	Very High Frequency
VLL	Very Low Level
VLOS	Visual Line Of Sight
VMC	Visual Meteorological Conditions
WAM	Wide Area Multilateration

1.2. Definitions

The definitions of individual terms in the context of this project are listed below.

Term	**Definition**

Accuracy	In alignment with the EASA CNS definitions (EASA, 2019), accuracy is the degree of conformance between the estimated, measured or desired position and/or the velocity of a platform at a given time, and its true position or velocity.
C2	Bi-directional command and control communication link between the operator and the aircraft.
Collaborative UTM/ATM Interface	This is found where there is a high level of automation with machine-to-machine interfaces enabling real-time operations. The UTM and ATM interface does not require procedural rules. UTM data is seamlessly integrated into ATCO's tools. In extremis, the human's role is to supervise the overall system, rather than making individual operational decisions.
Cryptography	The conversion of data into a secret code for transmission over a public network.
Digital Certificates	Electronic credentials that bind the identity of the certificate owner to a pair of electronic encryption keys, (one public and one private), that can be used to encrypt and sign information digitally.
Drone*	A colloquial term commonly-used to refer to Remotely Piloted Aircraft System (RPAS) and Uncrewed Aircraft (UA).
Integrity	Integrity comprises of two components: measurement integrity (failure at point of data creation) and system integrity (failure during data transmission). In alignment with this, according to the EASA CNS definitions (EASA, 2019), integrity is the probability per operating hour of an undetected failure of a functional element that results in corrupted (erroneous) data, or a failure in the processing as specified, leading to the (partial) loss of otherwise available data. From an ATC Surveillance System perspective (EUROCONTROL, 2015), integrity-related characteristics appreciate the influence of errors and inaccuracies on the Quality of Service. In a narrow sense, "integrity" is traditionally associated to error rate issues while "accuracy" is introduced to convey a notion of precision. An important specialisation of integrity in this wider sense of "accuracy" is the notion of "relevance", understood as the subjective degree of adequacy of the service to its intended use. Integrity is further refined in three different performance characteristics: core errors, correlated errors, spurious and large errors of data items.
Monitoring	In alignment with the definition provided by CORUS (CORUS, 2019), subject to appropriate data-quality requirements, the monitoring service retrieves data from the tracking service and combines it with information related to non-cooperative obstacles and vehicles to provide an air situation status report for authorities, service providers, and operators, including pilots. This service may include operation plan conformance monitoring, weather limit compliance monitoring, ground risk compliance monitoring, electromagnetic risk monitoring.
Phase	A means of defining the stages of development of U-Space and categorising which services will be provided at each stage.
Procedural UTM/ATM Interface	This is found in a low-level automation interface where interactions between UTM and ATM actors have procedural agreements in place that enable near real-time operations for specifically validated functions, like access to an ATZ/FRZ. Such procedures could, for example, allow UA and PAV flight plan approval/rejection based on agreed rules. In practice, a procedural interface could manifest itself in the form of a phone call between aircraft operator and ATC.
Public Key Infrastructure	A framework for creating a secure method for exchanging information based on public key cryptography.
Telemetry	Data from flight instruments on board an aircraft related to the aircraft's identity, position, and intent.
Tracking	In alignment with the definition provided by CORUS (CORUS, 2019), the U-space Tracking service incorporates a position report submission sub-service. Any instance of the Tracking service receives all position reports in its area of interest. Tracks are built using a statistical process that can be assisted by having access to the operation plans of the flights.
Traffic Information	In alignment with the definition provided by CORUS (CORUS, 2019), this service provides the aircraft pilot or operator with traffic information and warnings about other flights – crewed or uncrewed – that may be of interest to the pilot. Such flights generally have some risk of collision with the pilot's own aircraft. The information on the location of the aircraft and other airspace users is collated through telemetry feeds and surveillance sources.
U-Space	A set of services and procedures to enable safe, efficient and secure access to airspace for high numbers of UA.
UAS	An umbrella term for the equipment and systems that enable UA to operate including the ground station and communications equipment.
Volume	A 3D region of airspace in which a specific set of U-Space services are provided depending on the ground and air risk. Volumes are also differentiated by their equipage and entry requirements.

*This project covers aircraft of all types and sizes, using the term 'Uncrewed Aircraft' (UA) interchangeably with 'drone'. This project also includes Urban Air Mobility (UAM) vehicles for which the crewed aircraft is defined as a Personal Air Vehicle (PAV). Where something applies to both UA and PAV, those terms or the generic term ‘aircraft’ is used.

2. Summary

Please note that all the use cases described in this document are fictitious.

However, inspiration for the use cases has been derived from: live trials either taking place or due to take place around the UK[1]; use cases devised for other SESAR Joint Undertaking projects including CORUS (CORUS, 2019) and GOF-USPACE (SESAR Joint Undertaking, 2020); and other ATM/UTM-related projects, namely the Connected Places Catapult (CPC) Open Access UTM project (CPC, 2019), the Airspace4All/NATS Drone Infringement Safeguarding project (Airspace4All, 2019) and the Risk-aware Automated Port Inspection Drone(s) (RAPID) project (CORDIS: EU Research Results, 2020).

All the use cases have a common set of requirements, as listed below:

a. There is a BVLOS UA or PAV operation which, for at least part of the operation, takes place in UK controlled airspace.
b. A real-time telemetry feed is required to send data to the ATS provider to support one or more of the services ATC are providing.
c. Each use case is purposefully designed to be ambitious and challenging in order to deduce the most stringent requirements. As such, use cases in U1 phase, which have a very restricted number of U-Space services and don't have an ATM/UTM interface, have been excluded.
d. Each use case is designed to be realistic in the short to medium term and not too advanced as to seem unattainable with current technology. As such, use cases with a U4 phase have been omitted.
e. The use cases and scenarios are UAS technology agnostic, including the telemetry systems and aircraft equipage, to allow for a variety of different potential solutions.

Whilst accommodating the above requirements, the set of use cases taken collectively was purposefully devised to encompass a range of applications, volumes and phases as detailed in Table 1.

Use Case	Title	Volume				Phase	
		X	Y	Zu	Za	U2	U3
1	State Surveillance	✓			✓		✓
2	Medical Supply Mission	✓			✓		✓
3	Offshore Inspection		✓		✓	✓	

[1] Where this is the case, a link to the live trial has been provided in the use case summary.

4	Urban Air Mobility			✓	✓		✓
5	Coastguard Search and Rescue	✓		✓		✓	
6	High Altitude Platforms	✓			✓		✓
7	Port and Infrastructure Inspection		✓			✓	
8	Package Delivery			✓	✓		✓
9	Fire and Rescue Service			✓			✓

Table 1: Use case details

The use cases are each described in the following subsections. They are intentionally generic, however, under each one there are nominal and non-nominal scenarios. The scenarios are specific, detailed examples of how their respective use case could be realised on a particular operation, in a specific geographical area, involving named actors and organisations.

Each non-nominal scenario is built upon the details in its respective nominal scenario. The difference being there is an event that occurs which has the potential to compromise the UA / PAV telemetry data integrity.

3. Use Cases and Scenarios

3.1. Use Case 1: State Surveillance

Figure 1: Visual representation of Use Case 1[2]

Type of operation	General flight	Altitude	Area	Volume(s)	Phase
BVLOS	Stationary, route and area	VLL (<400ft)	Urban; densely populated	X → Za → X	U3

Table 2: Use case 1 parameters

3.1.1. Use Case Summary

Remote, airborne surveillance of an area is required in a densely populated region. In order to provide this service, a remotely piloted UA is required. The drone, flown for this mission to and from a depot to the geographical location of interest, must operate in a Za volume of controlled airspace. As such, the operator must submit an operation plan and will receive tactical advisory and/or instructions in case of conflict.

Real-time telemetry data transmission of the drone's location is required by the ANSP for U-Space services including monitoring, geo-fencing, and tactical conflict resolution.

[2] Image source: https://www.ibtimes.co.uk/uk-london-airport-police-use-surveillance-drones-counter-terrorism-operations-1498069

3.1.2. Nominal Scenario: Protest Surveillance

Actors	Supporting Actors
• Remote drone pilot Police Officer (PO) • Airport controller • USS	• Police Service • Protestors

Table 3: Actors in the use case 1 nominal scenario

The Police Service require airborne surveillance for a large protest march in a central metropolitan region. The drone's vantage point provides a wide geographical field of view from above showing the movement of the crowd and its behaviour on a macro level. This insight enables enhanced tactical coordination of police activities and a quicker response to situations that unfold on the ground. This, in turn, ensures a higher level of safety for the police, the protestors and the general public.

The PO is based in a central control centre. The PO controls the BVLOS drone flight, including the take-off procedure from the drone depot in X airspace, flying through Za airspace to the vicinity of the central metropolitan region protest, conducting the airborne mission and the flight back. En-route to the protest site, the ATCOs and PO communicate tactical de-confliction measures where required to maintain safe separation from other air traffic. To lower the ground risk for the en-route portion of the operations, the drone is flown down the river Thames until it needs to diverge to travel to the protest site.

When the drone has reached a pre-arranged waypoint in proximity to the protest area, the remote pilot establishes communication with the ground based Police Service who detail where they need the drone surveillance. The PO continues the BVLOS operation and flies the drone within a pre-authorised area within the Za volume. The area is geo-fenced to prevent infringements of other drones and geo-caged to prevent excursions of the Police Service drone. The geo-fence and geo-cage areas are set up pre-flight via the USS. ATCOs ensure crewed air users remain clear of the Police Service drone and put in place a temporary airspace restriction. If there is an instance where an airspace user infringes on the geo-fenced area, e.g. a heli-med flight, ATCOs liaise with the PO for tactical advisory and/or instructions to ensure safe separation is maintained.

3.1.3. Non-Nominal Scenario: Rogue Operator

Additional Actors
• Rogue operator

Table 4: Additional actors in the use case 1 non-nominal scenario

Data integrity threat: Malicious attack causing an airborne threat to the signal integrity

During the BVLOS operation, the PO is alerted to a loss of data integrity. The Police Service believe a malicious actor in the vicinity of the drone is deploying signal interference technology to jam and therefore disrupt the C2 datalink.

There is a threat to the drone operation as, if the jamming attempt were to be successful, the PO's ability to control the drone's behaviour would be severely compromised. This could lead to an increased risk to the people in the protest march and the Police Service on the ground as the drone could be weaponised.

The PO advises ATC of the situation.

When the loss of data integrity is detected, the drone automatically descends and lands in a pre-selected safe zone clear of people and obstacles while the ground team search for the offending rogue operator and the jamming equipment. The Police Service locate and detain the rogue operator and seize the equipment. Once confirmation of the seizure is relayed to the remote PO, ATC is contacted to validate that the Police Service drone can become airborne again. The drone then takes off and resumes its operation.

3.1.3.1. Alternative non-nominal scenarios

- Unintentional jamming when the Police Service drone flies by areas of high electromagnetic activity and signal density (e.g. in very dense drone traffic areas).
- Unintentional jamming when the Police Service drone flies by buildings and large steel structures which cause electromagnetic reflection, absorption and distortion.
- The PO-ATC communication could be jammed as well as the drone-PO telemetry feed, rendering a crucial means of mitigation in the non-nominal scenario above unusable.

3.2. Use Case 2: Medical Supply Mission

Figure 2: Visual representation of Use Case 2[3]

Type of operation	General flight	Altitude	Area	Volume(s)	Phase
BVLOS	Route	VLL (<400ft)	Urban; Densely populated and over sea/unpopulated	Za → X	U3

Table 5: Use case 2 parameters

A UA mission is required to transport medical supplies. Near the origin, the region is densely populated and there is an airport in the locality. The preferred route taken intersects a CTR, designated a Za controlled airspace volume. For the en-route section and the latter part of the flight, it is X volume airspace. Prior to the UA mission, the operator must submit a UA operation plan via U-Space through a USS's portal. Once ATC validation of the plan has been received by the UA pilot, the mission can take place.

During the flight, real-time telemetry data is transmitted to the ANSP via the surveillance data exchange which allows other U-Space services to be provided to the UA pilot. This includes the position report submission sub-service, tracking, monitoring and the provision of tactical advisory and/or instructions in case of conflict during the flight.

[3] Image source: https://www.emergency-live.com/wp-content/uploads/2020/02/Drone-trasporto-medicinali-750x430-1.jpg

3.2.1. Nominal Scenario: Southampton to Isle of Wight medical supply mission

Actors	Supporting Actors
• SolentMediDrone UA remote pilot • Operational ATM procedures officer • Airport approach controller • USS	• Southampton General Hospital staff • St Mary's Hospital Pathology Department staff

Table 6: Actors in the use case 2 nominal scenario

Inspiration: https://www.southampton.ac.uk/news/2020/05/drone-trial-delivery.page

St Mary's Hospital's Pathology Department on the Isle of Wight requires medical supplies from Southampton General Hospital urgently.

The majority of the route between the two hospitals is in X airspace over the Solent. The urgency of the mission requires a UA as opposed to the alternative mixed modes of transport (ground transport and ferry).

A private company SolentMediDrone supplies the NHS with the medical delivery UA service between the two hospitals.

The medical delivery UA is a multi-rotor, remotely piloted, EVTOL vehicle, designed to take off and land on hospital helipads.

There is a collaborative ATM/UTM interface and a surveillance data exchange enabling the operational ATM procedures officer to inspect and validate UA flight requests digitally through ATC systems. SolentMediDrone's remote UA pilot issues a request for a route through the CTR via their USS portal. The submission includes information pertaining to the nature of the flight which provides sufficient information to assess the relative priority of this flight over others. The flight request is granted by a nearby airport approach controller and the validation of the plan is sent back to the UA pilot via the USS.

During the flight, the medical delivery UA flight's position is displayed on ATC situation displays. ATC tracks the UA using the telemetry data feed in real-time as it progresses through and exits the CTR along its pre-defined route, providing a tactical deconfliction service to the UA pilot to ensure separation from crewed traffic.

During the Solent crossing and the latter part of the flight, the UA travels through an X volume of airspace where the USS continues to track and monitor the flight, but services including tactical deconfliction are no longer provided by ATC. The UA lands at the helipad at St Mary's hospital, Isle of Wight where the medical cargo is offloaded from the UA.

3.2.2. Non-nominal Scenario: Bird strike

Additional Actors
• Other aircraft pilots • Other remote UA pilots

Table 7: Additional actors in the use case 2 non-nominal scenario

Data integrity threat: Unintended/natural event which causes a loss of signal integrity

This scenario builds on the Southampton-Isle of Wight based nominal scenario. As the medical delivery UA is ascending from the helipad at Southampton General Hospital, despite the onboard Detect and Avoid (DAA) system, the UA collides with a fast-moving bird causing catastrophic damage to one of the UA's rotors and a temporary loss of telemetry data signal integrity. Due to the built-in safety features of the UA, the UA maintains the ability to fly and land in a controlled manner post-incident.

When the bird strike occurs, the UA issues an automatic alert to the pilot which is relayed to the USS.

In this scenario, in U-Space phase U3, a tactical emergency management service is provided. This service provides assistance to a UA pilot experiencing an emergency with their UA, and communicates emerging information to interested parties (CORUS, 2019). As such, once the USS has received the alert, a local emergency notification is promulgated to other airspace users including crewed traffic in the vicinity via the UTM. ATC are notified of the imminent emergency landing via the collaborative interface with UTM. With this information, ATC would provide tactical deconfliction to other airspace users.

ATC track and monitor the movement of the UA using the surveillance data exchange as it makes its emergency landing in the Hollybrook Cemetery adjacent to the hospital by utilising real-time UA telemetry data. Simultaneously, the telemetry signal is monitored for any further losses of integrity.

3.2.2.1. Alternative non-nominal scenarios

- A malicious actor may target the drone for its payload, attempting to cause the drone to descend in an unplanned location.
- Fictitious telemetry signals which 'create' fake drone flights to interfere with the medical drone operation.
- Deterioration in the meteorological conditions, especially over the sea (i.e. dense fog).

3.3. Use Case 3: Offshore Inspection

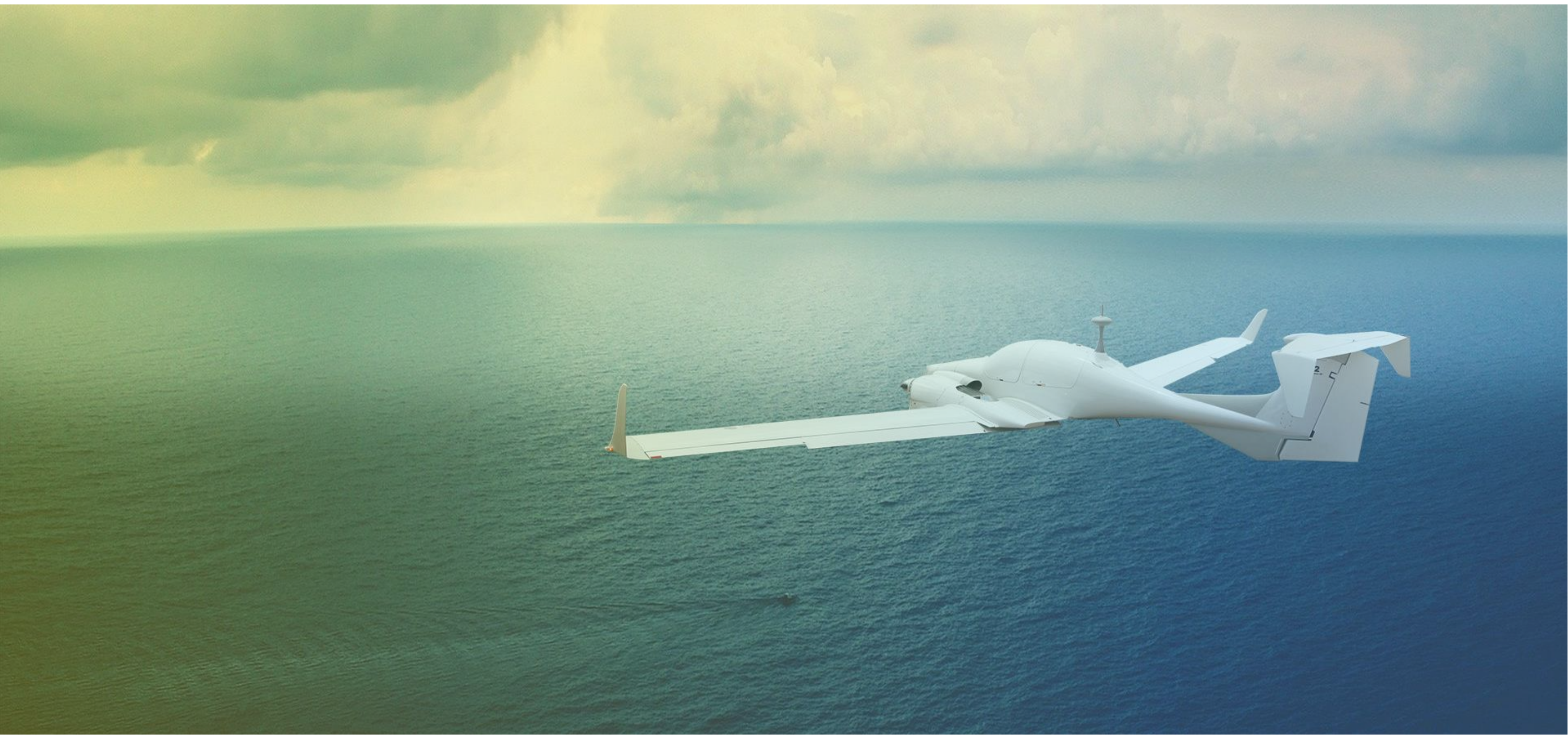

Figure 3: Visual Representation of Use Case 3[4]

Type of operation	General flight	Altitude	Area	Volume(s)	Phase
BVLOS	Stationary, route and area	Exceed VLL, <4,000 ft	Over the sea	Za → Y → Za	U2

Table 8: Use case 3 parameters

A remote UA pilot conducts an operation to inspect an engineering facility offshore. Exploiting UA for this purpose offers several benefits over its conventional counterpart: compared to helicopter flights, UA can be deployed quicker, are less costly to maintain and, being uncrewed, offer improved safety and lower operational cost.

The operator must submit a UA operation plan prior to the flight which includes authorisation to access the rig's exclusion zone. ATC strategically deconflicts the UA's operation plan with known offshore traffic, then provides flight monitoring and ATS Flight Information Service (FIS) during flight.

A 500m exclusion zone exists around the engineering facility to mitigate the risks posed by the close proximity of air traffic to the oil rig. Within the exclusion zone, the rig's offshore radio station provides an Offshore Communication Service (CAA, 2015). The radio station provides weather

[4] Image source: https://www.aeroexpo.online/prod/aeronautics-ltd/product-169150-503.html

information and, if the UA wishes to land, can issue an instruction as to whether the flight deck is available.

The UA must be electronically conspicuous throughout the flight for ATC situational awareness in mixed use, unsegregated airspace.

3.3.1. Nominal Scenario: Inspection of North Sea oil rig

Actors	Supporting Actors
• UA remote pilot • Airport Approach/Offshore Controller • Oil rig operator	• Command centre staff

Table 9: Actors in the use case 3 nominal scenario

Inspiration: https://www.worldoil.com/news/2019/9/9/flylogix-total-launch-north-sea-drone-initiative

Inspiration: https://www.nats.aero/news/ground-breaking-north-sea-helicopter-safety-system-goes-live/

An offshore energy provider's offshore oil rig platforms in the North Sea needs a visual inspection. The energy provider has several UA on stand-by operated from a Scottish airport. These are supported by a rota of BVLOS UA pilots stationed in an onshore command centre.

The pilot follows the regular process of registrations, pre-flight checks and the completion of a UA operation plan. ATCOs, based in Scotland, provide the strategic de-confliction service and advise the pilot that the slot chosen is available.

The fixed-wing UA takes off from a Scottish Airport. This initial phase of the flight is in a Za controlled airspace volume. The UA follows a pre-planned route over the North Sea. The operation takes place in low-level airspace where a UA and helicopter route structure exists and movements are procedural. Provides control instructions to the UA pilot based on the real-time telemetry feeds from the UA and other airspace users and using surveillance systems. This data gives the ATCOs situation awareness and the ability to provide tracking and monitoring services too.

ATC communicates with the remote pilot via ground-based communication channels to reduce latency. Were the communication to involve uplink to, and relay by, satellites, the latency would be considerably longer.

The oil rig is situated outside the coverage area of ground-based radar. As such, the surveillance data from ground-based radar is unable to provide sufficient coverage for the entire flight; a secondary system, such as ADS-B, must be employed.

The UA pilot issues a request to enter the exclusion zone as it approaches the oil rig platform. Authorisation is given to the pilot from the oil rig. The rig provides weather information to the UA while is conducts its visual inspections.

The UA completes its inspections and notifies the oil rig as it exits the exclusion zone. Communication is re-established with ATC. The UA follows its operation plan back to a Scottish airport where it lands.

3.3.2. Non-nominal Scenario: Deterioration in meteorological conditions

Additional Actors
• Other aircraft pilots • Other remote UA pilots

Table 10: Additional actors in the use case 3 non-nominal scenario

Data integrity threat: Unintended/natural event which causes a loss of signal integrity

This scenario is based on the nominal oil rig inspection scenario. During the course of the operation, on the return flight after the inspection in the exclusion zone has been completed, the meteorological conditions worsen significantly and unexpectedly. The gusting wind speeds exceed the operational limit for the UA. The UA becomes unable to maintain course on its pre-planned route.

Through a predictive excursion warning tool, the UA pilot is pre-emptively made aware of the UA's behaviour. The pilot alerts ATC. ATC continue to monitor the separation of the UA with other airspace users on situation displays.

The UA's power consumption rate rises rapidly as it tries to counter the effect of the gusts of wind, depleting its fuel reserves faster than forecast. The UA's route deviation grows, as seen and monitored by ATC. There is a growing risk to the signal integrity as the conditions worsen and the deviation from the planned route increases. As the ability to control the UA reduces, the pilot decides to make an emergency landing in the North Sea. The pilot issues a PAN-PAN call to ATC. ATC informs other airspace users in the area. The remote UA pilot executes the ditching manoeuvre.

3.3.2.1. Alternative non-nominal scenarios

- A fault with the onboard processor causes a loss of telemetry data integrity.
- Unintentional jamming of the signal due to electromagnetic interference with the large steel oil rig platform.

3.4. Use Case 4: Urban Air Mobility (UAM)

Type of operation	General flight	Altitude	Area	Volume(s)	Phase
BVLOS	Route	Subject to varying altitude restrictions along the routes, typically 1,500-2,000 ft	Urban	Za → Zu → Za	U3

Table 11: Use case 4 parameters

Note: The expectation is that UAM aircraft will be certified to similar requirements as crewed aviation (GA as a minimum, and possibly more stringent certification akin to Civil Air Transport (CAT) aircraft). The telemetry data transmissions will therefore likely need to comply with certain standards which in turn has implications on the integrity of the telemetry data.

UAM operators provide a fast, direct, sustainable transportation solution as an alternative to congested, ground-based modes of transport or noisy, polluting and expensive helicopter rides. There are several different forms of UAM aircraft, some of which are able to take off and land both horizontally from a runway and vertically from a vertiport.

This case study sees a UAM aircraft offer an intra-urban air taxi service, transporting a small group of passengers across a densely populated region.

The UAM aircraft is semi-autonomous with input provided by a remote pilot.

As the route is above a populated, urban area with other air traffic also navigating in the vicinity, the airspace is designated as a Zu volume. Consequently, prior to take off, the operator must submit a flight plan via U-Space through a USS's portal. Once validation that the plan is strategically deconflicted, the operation can take place.

With the provision of real-time telemetry data to the ANSP/USS via the surveillance data exchange, the remote pilot will receive tactical advisory and/or instructions in case of conflict during the flight from the ATS/UTM provider.

3.4.1. Nominal Scenario: Metropolitan region to Airport Flight

Actors	Supporting Actors
• UAM Ltd remote pilot • Aerodrome Controller • Airport controller	• Command centre staff

Table 12: Actors in the use case 4 nominal scenario

UAM Ltd are transporting 3 passengers in their EVTOL aircraft between two city airports.

UAM vehicles travel between vertiports along specially defined, segregated UAM one-way routes (defined as Zu volumes) between the airports. These routes avoid the conventional aircraft and helicopter traffic. The UAM vehicles are equipped with DAA equipment to ensure they remain well clear of other UAM traffic.

ATC provide a Traffic Information (TI) service to the remote pilot. Real-time telemetry feeds from the UAM Ltd aircraft and other airspace users, in conjunction with the surveillance data exchange service, allow ATC to track and monitor their locations relative to the ground, their routes, and the other airspace users.

There is a collaborative ATM/UTM interface enabling real-time, digital communication via ATC systems between the pilot and ATC.

3.4.2. Non-nominal Scenario: Loss of Comms Link

Additional Actors
• Other helicopter pilots • Other PAV pilots

Table 13: Additional actors in the use case 4 non-nominal scenario

Data integrity threat: Malicious attack which causes a compromised link

This scenario is an expansion on the nominal UAM Ltd scenario. As the UAM Ltd aircraft travels away from the metropolitan region along a Zu volume UAM corridor, there is a malfunction in the transmission of the surveillance data which causes a loss of signal integrity of both functions of the Command and Control (C2) link between UAM aircraft and remote pilot. The data appears to be corrupted and then the telecommand uplink and the telemetry data downlink cease completely. A real-time telemetry feed from the aircraft is no longer possible, resulting in ATC no longer being able to see the position of the UAM Ltd aircraft, which in turn poses an issue for the situational awareness of the Controller.

Without incoming commands from the remote pilot, the UAM aircraft, equipped with a DAA capability, flies autonomously, with the onboard back-up systems assuming control.

The remote pilot informs ATC of the situation. ATC instructs all traffic in the vicinity to hold or adjust course to maintain sufficient distance from the anticipated position of the UAM aircraft.

The C2 link is restored after 5 minutes. The remote pilot informs ATC that control has been restored. The telemetry feed from the aircraft for ATC is restored. ATC respond by issuing instructions to the surrounding traffic to resume their intended flight paths, where doing so does not pose a risk to the separation distances between them.

3.4.2.1. Alternative non-nominal scenarios

- Unintentional jamming caused by flying in high density drone traffic.
- Unintentional jamming when flying near high rise buildings which cause reflection, obstruction and distortion of electromagnetic signals.

3.5. Case Study 5: Coastguard Search and Rescue

Figure 4: Visual representation of Use Case 5[5]

Type of operation	General flight	Altitude	Area	Volume(s)	Phase
BVLOS	Area	Exceed VLL	Remote, sparsely populated	Zu → X → Zu	U2

Table 14: Use case 5 parameters

A remotely piloted, small, fixed wing, BVLOS UA supports the coastguard in search and rescue operations in a surveillance capacity. The UA helps a coastguard agency carry out its time critical, reactive search and rescue, and international counter pollution obligations.

The airspace the UA needs to transit through uncontrolled and controlled airspace; X and Zu volumes.

A real-time telemetry data feed from the UA and the surveillance data exchange service enable real-time location-based services including tracking, tactical conflict resolution with crewed traffic and traffic information.

[5] Image source: https://www.coptrz.com/drone-in-sar-operations/

A search and rescue operation requires the assistance of a UA to expedite the surveillance of a large area of land to locate missing people.

3.5.1. Nominal Scenario: Maritime and Coastguard Agency

Actors	Supporting Actors
• Coastguard officer remote pilot • FISO	• Search and Rescue (SAR) groups • Persons in distress

Table 15: Actors in the use case 5 nominal scenario

Inspiration: https://cp.catapult.org.uk/mca-drone-demonstration-and-development-pathfinder/ (Note that this case study uses a large, military-derived drone whereas we are considering a smaller UA in this instance).

The coastguard has received reports of a family on a kayaking expedition in Wales who are in distress on the coast. SAR groups on the ground have been dispatched, but they have requested UA surveillance support to aid their search.

A coastguard officer is based in central control centre. They control the UA throughout its BVLOS operation.

The UA is equipped with a suite of sensors including: a maritime radar, an electro optic payload, satellite communication, an automatic identification system receiver and an emergency position-indicating radio beacon receiver.

The UA takes off from a drone depot in Zu airspace. There is a procedural interface between UTM and ATM with a flight plan submitted and approved for the take-off and landing portions of the flight.

The route to and area around the search site is a pre-defined, segregated, geo-fenced X volume of airspace.

The UA successfully conducts its mission, finding the family and coordinating the ground-based SAR team to their precise location.

After the operation is complete, the UA flies back to the depot.

3.5.2. Non-nominal Scenario: GNSS-spoofing

Additional Actors
• Individual behind the signal spoofing

Table 16: Additional actors in the use case 5 non-nominal scenario

Data integrity threat: Malicious attack which results in an airborne threat caused by tapping the feed, editing and retransmitting it

This scenario builds upon the nominal scenario. During the flight, the UA's apparent location is altered by spoofed GNSS signals. An offset equating to approximately 3nm is being applied to the location data which is received by the UA's GNSS sensor, ingested into the UA's processor and transmitted.

This poses a significant risk to other airspace users as the instructions issued by remote pilot are no longer based on accurate data and could therefore potentially be putting the UA and other airspace users at risk of collision. Were the situation not resolved, there would be a further risk once the UA flew back to land and entered Zu airspace; that the FISO's real-time Situational Awareness (SA) would also be compromised.

The loss of telemetry data integrity is identified by an onboard system[6].

The remote pilot is made aware of the spoofing through an alert in their flight control system. The remote pilot informs the FISO by VHF radio. The coastguard officer follows procedure, cuts the power to the UA and deploys the UA's parachutes so it makes a quick but controlled landing.

Post-incident, an investigation is launched to determine the source of the GNSS-spoofing signal.

3.5.2.1. Alternative non-nominal scenarios

- Signal coverage issues in remote locations.
- Deterioration in the meteorological conditions, especially over mountainous terrain (i.e. heavy snow).

[6] The means in which this is done, and the technological solution used to do so, are not specified as the scenario is intentionally agnostic to this.

3.6. Case Study 6: High Altitude Pseudo-Satellites (HAPS)

Figure 5: Visual representation of Use Case 6[7]

Type of operation	General flight	Altitude	Area	Volume(s)	Phase
BVLOS	Route, stationary and area	High Altitude, exceeds controlled airspace	Mixture	X → Za	U3

Table 17: Use case 6 parameters

Using a network of HAPS, which are a type of UA, high speed broadband can be offered as a service to hard-to-reach locations on the ground.

The UA are replaced on a regular basis for maintenance and inspections. The UA are remotely piloted as they travel to/from an airport to their high-altitude holding destination and vice versa.

The ascent from an airport takes the UA through Za volume controlled airspace until they reach an altitude above the airline operating altitudes, that is, above FL600. In this transit of controlled airspace, real-time telemetry of the UA is shared between ATM and UTM systems via the surveillance data exchange service. The telemetry is transmitted on to ATC via the collaborative interface. This enables ATC to provide the mandatory real-time location-based services.

[7] Image source: https://spacenews.com/uk-military-orders-third-high-altitude-pseudo-satellite-from-airbus/

3.6.1. Nominal Scenario:

Actors	Supporting Actors
• HAPS remote pilot • Approach Planner Controller • Approach Executive Controller • Area Planner Controller • Area Executive Controller • Aerodrome Planner Controller • Aerodrome Executive Controller	• Command and control centre staff

Table 18: Actors in the use case 6 nominal scenario

Inspiration: https://www.flightglobal.com/civil-uavs/hapsmobile-to-flight-test-high-altitude-pseudo-satellite-hawk30-in-new-mexico/138838.article

Inspiration: https://www.stratosphericplatforms.com/

HAPSMobile is a US company which has expanded its HAPS operations overseas. It has launched several dozen solar-powered high altitude, large wingspan UA to provide an internet service to remote locations with limited ground-based broadband over the south of the UK. Lower latitudes are chosen owing to the higher annual daylight hours.

A remote pilot in the command and control centre has received a notification that one of the UA is required to descend to an airport for routine airframe inspection. It is currently in formation, providing internet coverage over a southern region of the UK, providing high speed broadband in a remote region where local topographical constraints restrict access to high speed broadband services.

The only other air traffic operating at the UA's current altitude above Class C airspace are the other HAPSMobile UA. At this altitude, the UA fly according to IFR rules. Strategic and tactical flight planning coordinated by the command and control centre ensures the UA remain separated.

The UA ascend and descend in a diurnal pattern. They utilise the solar energy they generate during the day to ascend gradually in altitude. Then, during the night, the UA gradually descend in altitude, reducing their power demand.

As the UA descends on its planned route to the airport, it passes into controlled airspace where airlines and other traffic operate. Hence, ATC offers both strategic and tactical deconfliction services to ensure separation between the UA and crewed traffic on its descent, issuing instructions to the pilot and the other airspace users when necessary. ATC track and monitor the UA's progress in real-time.

The remote pilot submits a flight plan to ATC via U-Space. As a collaborative interface between UTM and ATM exists, the flight plan is transmitted digitally to ATC systems. Once ATC ascertain that there are no conflicts, a validation message is returned. The remote pilot then begins to execute the UA descent. A tactical deconfliction service is provided throughout the transit of controlled airspace.

3.6.2. Non-nominal Scenario: HAPS Processor Failure

Data integrity threat: Unintended/natural event which causes a loss of signal integrity

This scenario is based on the nominal scenario. The processor in the UA fails on descent, leading to a loss of integrity of the downlinked telemetry feed from the UA. The UA is above airline traffic, but is on the descent phase.

The UA remote pilot is alerted to the loss of integrity and can no longer rely on the accuracy of the real-time location updates. The pilot issues a command to the UA to maintain altitude while the issue is being investigated to find out whether it is possible to re-establish the integrity of the telemetry feed. However, without knowledge of the UA's location, it is not known whether the UA has received and processed the command. Hence, ATC instructs crewed traffic in the region to adjust their routes and ensure their safe passage through the airspace.

Due to the design of the HAPS vehicle, it travels slowly relative to other airspace users, but has a very large glide range. Thus, not knowing its real-time location for an extended period of time can result in a very large uncertainty in its position.

The real-time telemetry feed integrity is re-established after 15 minutes and the UA pilot is able to fly the UA down to the ground where maintenance teams carry out post-incident analysis to determine the cause of the processor failure.

3.6.2.1. Alternative non-nominal scenarios

- Malicious jamming or spoofing of the signal by organised, rogue actors.

3.7. Case Study 7: Windfarm Inspection

Figure 6: Visual representation of Use Case 7[8]

Type of operation	General flight	Altitude	Area	Volume(s)	Phase
BVLOS	Route & Area	Below VLL	Remote, sparsely populated	X → Y	U2

Table 19: Use case 7 parameters

A UA transits a windfarm while a swarm of UA simultaneously carry out an aerial inspection of several of the wind turbines.

A real-time telemetry data feed from both the transiting and inspecting UA and the surveillance data exchange service enable real-time location-based services including tracking, tactical conflict resolution with crewed traffic and traffic information.

As this use case is envisaged to take place in U2 U-Space phase, there is a procedural ATM/UTM interface.

3.7.1. Nominal Scenario: Scottish Windfarm

Actors
• UA pilot

[8] Image source: https://www.youtube.com/watch?v=FbbkHyFTW_8

• Airport Controller

Table 20: Actors in the use case 7 nominal scenario

Several turbine blades on the turbines at a Scottish windfarm need a civil engineering inspection. A swarm of four agile, light UA are required at the inspection site and are deployed from the windfarm management centre onsite. The swarm of UAs collectively follow the navigational instructions of a single, remote pilot. The flight configuration of the UA within the swarm, and their individual behaviour is largely automated and their in-built DAA capability ensures they maintain safe separation from each other.

Meanwhile, a UA is deployed on a route which takes it through the windfarm. The route from take-off to inspection site is designated as a pre-defined, segregated UA corridor of type X volume airspace. The route is bounded by a geo-cage. The windfarm site itself is a pre-defined Y volume of airspace.

From the transiting UA operator's perspective, the windfarm is both a potential risk and an opportunity. The wind turbines are a low-level flight hazard for the transiting UA and the route must therefore be planned to keep a suitable separation from the turbine towers and blades and any inspection drones or other airborne vehicles that may be in operation. As the location has been determined optimal for wind turbines, the topography and meteorological conditions are highly likely to indicate frequent strong winds which may pose a flight hazard to the UA, suggesting it may be advisable to find an alternative route. On the other hand, windfarms represent a relatively sterile airspace as most, if not all, GA and commercial traffic are likely to keep well clear of the airspace. In addition, windfarms are remote, sparsely populated (and therefore lower ground risk) regions with good connectivity and infrastructure. For these reasons, it may in fact be *preferable* to route UA through airspace in and around the windfarms.

Both pilots for the UA swarm and the transiting UA use the Drone Assist app (NATS, 2020) to submit their route and area requests for their flights. Once the submission is logged through the app. Their flight plans don't conflict, and their segregated portions of the airspace are established. The operations can then commence.

After the operation is complete, the swarm of UA flies back to the management centre while the transiting UA continues its flight to its intended destination.

3.7.2. Non-nominal Scenario: GNSS-spoofing

Additional Actors
• Individual behind the signal spoofing • CAA

Table 21: Additional actors in the use case 7 non-nominal scenario

Data integrity threat: Malicious attack which results in an airborne threat caused by tapping the feed, editing and retransmitting it

This scenario builds upon the nominal scenario. During the flight, one of the UA in the swarm deviates off-course. An individual uses communications equipment to spoof the GNSS signal causing the UA to change direction, heading out of the inspection site and through the no-fly zone in the direction of a nearby airport.

The course deviation is detected by the pilot as the UA breaches the geo-caged area. Its location is monitored via the Drone Assist app.

The pilot alerts the airport controller by phone of the situation so the information can be relayed to the other airspace users.

The Drone Assist app alerts the transiting UA which takes appropriate action to stay clear of the deviating drone.

The pilot commands the UA swarm to make an emergency landing in an attempt to regain control of the erroneous UA. In addition, the pilot wishes to avert the situation where another UA is spoofed and changes course.

The Controller issues tactical instructions to aircraft in the area of the airport and the UA, ensuring they are clear of the area while the UA remains under unauthorised control.

Counter drone technology is employed at the nearby airport which successfully ensures the UA descends at a gradual rate to the ground in a designated area. The deviating UA, and the others in the swarm, are seized by the CAA's UA systems unit for post-incident forensic analysis. Once the seizure is confirmed, the controller can reinstate use of the airport runways and resume operations.

3.7.2.1. Alternative non-nominal scenarios

- Unintentional jamming of the signal or radar interference caused by the wind turbines.
    - If there is a loss of integrity of the C2 link, this could even cause the transiting and inspection UAs to collide.

3.8. Use Case 8: Package Delivery

Figure 7: Visual representation of Use Case 8[9]

Type of operation	General flight	Altitude	Area	Volume(s)	Phase
BVLOS	Route	VLL (<400ft)	Urban; Densely populated	Za → Zu → Za	U3

Table 22: Use case 8 parameters

One of the largest potential markets for UA BVLOS operations in the UK, and around the world, is airborne package delivery. UA offer a means of providing last-mile logistics – taking packages from a distribution centre to customers' homes or offices, in the quickest way available. This service offers the opportunity to respond to customers' needs faster than conventional methods while not compromising on convenience and user experience.

The delivery UA are generally capable of transporting packages weighing of the order of a few kilograms. Depending on the routes they are designed to services, various eVTOL designs are used including single, dual and transition phase[10].

[9] Image source: https://www.ibtimes.co.uk/uk-london-airport-police-use-surveillance-drones-counter-terrorism-operations-1498069
[10] The three different types of eVTOL are described in a vertical mobility study (Porsche Consulting, 2018), Single phase eVTOLs have fixed rotors optimised for vertical motion. Dual phase UAs have a mixture of vertical and horizontal rotors which can be operated independently depending on the phase of flight. Transition phase eVTOLs have rotors which are able to tilt while in use to alter the direction of thrust.

This case study sees an autonomous UA transport a small cargo from a distribution centre, across a densely populated region, to a customer's garden. The UA deposits the package and returns to the distribution centre.

Although the UA operate autonomously and have DAA capabilities, they are overseen by a remote pilot who can issue commands to any of the UAs in the fleet if necessary.

As the route is, in part, near an airport and above a populated, urban area, the airspace is designated as Za and Zu volumes. Consequently, prior to take off, a flight plan must be submitted via U-Space through a USS's portal. Once validation that the plan is strategically deconflicted, the operation can take place.

Real-time surveillance data is relayed to the ANSP/USS such that location-based services can be provided.

3.8.1. Nominal Scenario: Drone Package Home Delivery

Actors	Supporting Actors
• Drone remote pilot	• Warehouse staff

Table 23: Actors in the use case 8 nominal scenario

Inspiration: https://www.amazon.com/b?node=8037720011

A warehouse located adjacent to an airport is strategically placed to optimise ground transportation links and can also distribute airfreight to locations in the surrounding area.

The warehouse is equipped with automated cargo loading bays and UA take-off and landing infrastructure. This allows it to offer the drone package delivery service to customers within 7 miles of the centre.

Within the Za volume airport CTR, several drone corridors have been established to better manage the quantity of UA flights that the warehouse requires. Each of those corridors guides the UAs out of the CTR to concentrations of customers in different geographical regions. At the same time, those corridors are designed to avoid the common flight paths at VLL arriving and departing from the runways. At the end of the corridors, once outside the CTR, are airspace is a Zu volume owing to the high population density of the residential streets below.

A customer in a nearby town places an order for a product to be delivered by drone. When the order comes in, an automated system identifies the optimal flight path using one of the Za UA corridors and through the Zu airspace beyond. The return route request is submitted to the USS. As this scenario takes place in U-Space phase U3, the request is automatically sent to the ATC systems which automatically confirm that the request is strategically deconflicted with known crewed traffic. The USS ensures strategic deconfliction with other known uncrewed traffic.

The product is packaged and loaded into the underside of the dual phase UA. Once the flight route is approved, the US takes off and travels autonomously to the nearby town where it deposits the package. The UA then returns back to the warehouse. A remote pilot surveys the fleet of UA in case a command needs to be sent.

3.8.2. Non-nominal Scenario: Malicious code

Additional Actors
• Aerodrome Controller • Airport Counter-Drone Team • Pilots of other airspace users • CAA

Table 24: Additional actors in the use case 8 non-nominal scenario

Data integrity threat: Malicious code

This scenario is based on the nominal scenario. During the initial phase of flight as the UA transitions from hover to forward flight, an integrity alert is issued via the USS app to the UA pilot.

The surveillance system has experienced a cyber-attack. A virus has penetrated the system and manipulated the transmitted real-time telemetry feed, causing the data to be scrambled and unusable.

The loss of real-time telemetry data integrity detrimentally impacts the ability to provide safety-critical U-Space services. This poses a safety risk to surrounding airspace users and people on the ground.

The pilot responds by alerting an aerodrome controller who issues instructions to crewed aviation in the area so as to ensure they avoid the UA.

Counter-drone technology is deployed by staff at the airport to safety and efficiently ground the UA. The UA is seized by the CAA's UA systems unit for post-incident forensic analysis.

3.8.2.1. Alternative non-nominal scenarios

- Unintentional jamming caused by flying in high density drone traffic.
- Unintentional jamming when flying near high rise buildings which cause reflection, obstruction and distortion of electromagnetic signals.

3.9. Use Case 9: Fire and Rescue Service

Figure 8: Visual representation of Use Case 9[11]

Type of operation	General flight	Altitude	Area	Volume(s)	Phase
BVLOS	Area	VLL (<400ft)	Urban; Densely populated	Zu	U3

The Fire and Rescue Services (FRS) operate a drone when responding to an emergency, deploying it at the incident site. The FRS are assisted by live images and thermal imagery from drone onboard sensors. This allows an incident commander to assess the evolving situation from an airborne perspective safely, identifying the layout of the site, location and size of the blaze, and potential locations of casualties. It also enables the commander to coordinate the firefighters' actions.

The drone is deployed beside the fire truck, a safe distance from the incident. This is a rapid deployment in an emergency situation where creating and submitting a pre-flight plan is not possible. The Fire and Rescue Service has a General Exemption E4506 of the CAA Air Navigation Order to fly the drone outside of the normal commercial operations under emergency conditions.

[11] Image source: https://ukfiremag.mdmpublishing.com/drones-for-the-fire-and-rescue-services/

Real-time, high integrity telemetry data is required as the drone is operating in a hostile environment in relatively close proximity to buildings. The drone's sensor data provides operational data essential to the safety and success of the overall operation.

3.9.1. Nominal Scenario: Fire and Rescue Service Rapid Deployment

Actors	Supporting Actors
• Remote drone pilot • FRS controller • Aerodrome Controller • USS	• FRS firefighters • Civilians

Table 25: Actors in the use case 8 nominal scenario

Inspiration: https://www.westsussex.gov.uk/fire-emergencies-and-crime/west-sussex-fire-and-rescue-service/west-sussex-fire-rescue-service-drone-unmanned-aerial-vehicle/

The FRS is called to respond to an emergency situation at a warehouse in an industrial estate in the UK. Once at the scene of the blaze in the centre of a highly populated region of volume Zu airspace, the FRS deploy their drone.

The drone operator informs the USS and ANSP of its actions, creating a temporary geo-fence and geo-cage around the incident site. This ensures other unmanned and manned aircraft remain well clear of the area and do not interfere with the firefighting operation or fly near the smoke column.

The airborne drone is used to inspect the extent of the fire and coordinate activities on the ground. Although the drone pilot is relatively close to the drone's flight area and is in visual sight for the majority of the time, in order to access harder to reach areas of the site, and due to variable visibility caused by smoke and fire obscuration, the remote pilot conducts a BVLOS operation.

The civilians trapped inside the warehouse and the firefighters are faced with a potentially life-threatening situation as the rescue mission proceeds. The drone conducts its mission, providing surveillance data to the commander throughout the operation until the situation is under the control, the fire is extinguished, and the civilians have been located.

The drone lands and undergoes a post-flight inspection before being stowed and charged for its next deployment.

3.9.2. Non-nominal Scenario: Spurious Aircraft Data

Data integrity threat: Unknown threat which may cause a loss of signal integrity

During the operation, with the geo-fence active, the ANSP observes radar signals of what appears to be an unidentified aircraft flying in the locality of the incident. This poses a risk, both to the aircraft in question, and to the operation. Should the aircraft fly into the smoke column, the visibility would be severely reduced, potentially compromising the safety of the flight. Were the aircraft to fly close to the FRS drone, this could negatively impact on the safety of the FRS's operation. Were pre-emptive precautionary actions to be taken, grounding the FRS's drone while the nature of the other aircraft be ascertained and its intentions probed, the FRS controller would lose crucial surveillance information, potentially putting lives at risk.

The FRS controller is alerted to the developing situation, but before taking action the new entrant's signal is monitored closely, and, as time elapses, the flight path is observed to change in an erratic fashion. The signal is also temperamental, dropping out on several occasions.

It is determined that the aircraft is spurious radar data caused by signal interference, not an actual aircraft in the airspace. This information is relayed to the controller. There is a risk that the interference may detrimentally affect the FRS drone's C2 link, however, after a risk analysis is performed, the decision is taken to proceed with the operation. A post-incident investigation is launched to determine the cause of the spurious data and prevent a similar incident happening again.

3.9.2.1. Alternative non-nominal scenarios

- Unintentional jamming of the telemetry signal due to interference with steel structures around the industrial site.
- Unintentional degradation in SNR due to interference from high electromagnetic activity in the area.

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