PODIUM Demonstration Report

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PODIUM

PODIUM

This Demonstration Report is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 783230 under European Union's Horizon 2020 research and innovation programme.

Abstract

The Proving Operations of Drones with Initial UTM (PODIUM) is a SESAR/Horizon 2020 Very Large Scale Demonstration Project. The main objectives of PODIUM have been to demonstrate current state-of-the-art U-space/UTM concepts and systems in operational environments; to assess their maturity; and to make recommendations regarding their deployment.

PODIUM has performed 18 operational scenarios for multiple VLOS and BVLOS flights, involving 73 actual flights and 138 flight authorisation workflows, at Hans Christian Andersen Airport, Odense; the Drones Paris Region cluster, Brétigny-sur-Orge; Rodez-Aveyron airport; the Netherlands RPAS Test Centre, Marknesse; and Groningen Airport Eelde. The project has collected and analysed validation data from 41 completed post demonstration questionnaires; 5 facilitated de-briefing sessions; and observations from EUROCONTROL validation experts and partners.

Drone operators, air traffic controllers and supervisors strongly confirm the need for UTM/U-space solutions that can ease the burden of obtaining flight authorisations, and that increase situational awareness to enable safety and efficiency benefits during flight execution. They confirm the operational and technical acceptability of the current PODIUM solution for the flight preparation phase; the main area for improvement concerns the ability to provide situational awareness for drone pilots in the flight execution phase.

The PODIUM project is one of several large scale demonstration projects for U-space that are being performed within SESAR. The SESAR Joint Undertaking will consolidate the main findings of PODIUM and the other projects, in order to prepare a consolidated set of conclusions and recommendations for U-space at a "programme" level.

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1 Executive summary

The Proving Operations of Drones with Initial UTM (PODIUM) is a SESAR/Horizon 2020 very large scale demonstration project. The main objectives of PODIUM have been to demonstrate current state-of-the-art U-space/UTM concepts and systems in operational environments; to assess their maturity; and to make recommendations regarding their deployment.

PODIUM has performed 18 operational scenarios for multiple VLOS and BVLOS flights, involving 73 actual flights and 138 flight authorisation workflows at: Hans Christian Andersen Airport, Odense; the Drones Paris Region cluster, Brétigny; Rodez-Aveyron airport; the Netherlands RPAS Test Centre, Marknesse; and Groningen Airport Eelde. Further to familiarisation flights and mock-ups in late 2018 and early 2019, the bulk of the flights were performed in the period May to June 2019. PODIUM convened five visitors days attended by local stakeholders at each of the sites. A dissemination event was held at EUROCONTROL Brussels on 17 October 2019.

The project has collected and analysed validation data from 41 post demonstration questionnaires completed by participants; 5 facilitated de-briefing sessions; and observations from EUROCONTROL validation experts and partners. The demonstration results mainly rely on feedback from the participants (qualitative) and no quantitative statistical analysis (with significant test) has been performed.

Drone operators, air traffic controllers and supervisors strongly confirm the need for UTM/U-space solutions that can ease the burden of obtaining flight authorisations, and that increase situational awareness to enable safety and efficiency benefits during flight execution.

Drone operators, air traffic controllers and supervisors confirm the operational and technical acceptability of the current PODIUM U-space/UTM solution for the flight preparation phase (corresponding to U1 and some U2 services), albeit with a number of remarks.

Air traffic controllers and supervisors confirm the operational and technical acceptability of the current PODIUM U-space/UTM solution for the flight execution phase (corresponding to some U2 services), albeit with a number of remarks.

Drone operators have not confirmed the operational and technical acceptability of the current PODIUM U-space/UTM solution for the flight execution phase (corresponding to some U2 services), and have recommended a number of improvements, notably with regards to the need for enhanced situational awareness for operations “out in the field”.

This overall demonstration report represents a consolidation, a synthesis of the conclusions and recommendations in the individual demonstration reports for Odense [30], Brétigny [31], Rodez [32] and Marknesse/Eelde [33]. The main project-wide conclusions from the PODIUM demonstrations and the resulting recommendations are provided at paragraph 5.

The SESAR Joint Undertaking will consolidate the main findings of PODIUM and the other U-space projects, in order to prepare a consolidated set of conclusions and recommendations for U-space at a “programme” level.

The reader is invited to take a look at the videos on the SJU PODIUM website as a complement to reading this demonstration report.

2 Introduction

2.1 Purpose of the document

This document is the demonstration report for the SESAR/Horizon 2020 Proving Operations of Drones with Initial UTM (PODIUM) very large scale demonstration project. It describes the work performed, the main results, and the conclusions and recommendations from the overall PODIUM perspective. This document represents a consolidation of the individual site demonstration reports for Odense [30], Brétigny [31], Rodez [32] and Marknesse/Eelde [33].

The work has been performed by the beneficiaries: EUROCONTROL (lead), Airbus, DSNA, DELAIR, Drones Paris Region, Integra Aerial Services, Naviair, NLR, Orange and Unifly; and the third parties (including linked third parties and subcontractors)

2.2 Intended readership

The main PODIUM partners (beneficiaries, linked third parties, subcontractors) are invited to use this demonstration report as a record of the work performed and the main results from PODIUM. They are invited to use the findings of this report as an input to any further work that they may perform related to U-space.

The SESAR Joint Undertaking is invited to use this report - along with the reports from the other U-space demonstration projects - to develop a consolidated set of conclusions and recommendations for U-space at a “programme” level.

A number of external readers to SESAR – notably EASA, DG-Move, EUROCAE and the EUSCG – are invited to use this report as input to support collaboration on their activities related to U-space.

Finally, the PODIUM consortium welcomes the publication of this report as a public document, with a view to sharing our findings with any parties that are interested in the further development of U-space and UTM.

2.3 Background

This PODIUM demonstration report takes into account the following previous and ongoing work related to U-space:

- U-space Blueprint [27]
- SJU European Drones Outlook Study [28]
- Drones Helsinki Declaration and its successors [29]
- European ATM Master Plan: Roadmap for the safe integration of drones into all classes of the airspace [26]
- (CORUS) U-space Concept of Operations [21]
- PODIUM Concept & Architecture Description [18]
- PODIUM VLD Revised Demonstration Plan [17]

2.4 Structure of the document

This document takes into account the structure of the SESAR 2020 U-space study template [22]. In practice, the template has been modified to take into account the specificities of PODIUM and to be in line with the Revised Demonstration Plan for PODIUM [17].

The Executive Summary provides the reader with a short description of the work performed and the results. The Executive Summary has been deliberately limited to one page and, therefore, does not repeat the conclusions and recommendations at chapter 5.

Chapter 2 (Introduction) provides background information and "sets the scene" for the Demonstration Report as a whole.

Chapter 3 (Context of the Study) starts with a table indicating which PODIUM services and systems were actually used across the five operational sites in Denmark, France and the Netherlands. The chapter then describes the approach for performing the demonstration flights including the collection and analysis of the data. Two tables provide a summary of the objectives and success criteria, as well as the assumptions, described in the Revised Demonstration Plan [17]. The chapter ends with an explanation of the main deviations compared to the plan.

Chapter 4 (Study results) starts with two summary tables: the first summarises the readiness of the services for deployment; the second summarises the extent to which the objectives and criteria from the plan were satisfied during the demonstrations. There then follows a more detailed description of the extent to which the six objectives were satisfied, supported by the analysis of the data collected during the demonstrations. The chapter ends with an explanation of the degree of confidence with which the results should be treated.

Chapter 5 (Conclusions and recommendations) begins with a set of conclusions about the maturity of the services and capabilities used in the demonstrations. The recommendations describe the further actions required to support deployment including the need for work on standards and regulation.

Chapter 6 (References) provides a list of the reference material referred to in this report.

Finally, there are five appendices addressing: the detailed demonstration reports for the operational sites; the human performance, safety and security assessment reports; and the mapping of the PODIUM services to those used in CORUS.

2.5 Terminology

Term	Definition	Source of the definition
Beyond visual line of sight (BVLOS)	An operation where neither the drone pilot nor the observer maintains direct unaided visual contact with the RPA.	EASA NPA 2017-05
Command and Control (C2)	Ability of drones to communicate with their ground control station to manage the conduct of the flight, normally via a specific data link.	Manual on remotely piloted aircraft systems (ICAO Doc.

		10019)
Detect and avoid	The capability to see, sense or detect conflicting traffic or other hazards, and take the appropriate action to comply with the applicable rules of flight.	Manual on remotely piloted aircraft systems (ICAO Doc. 10019)
Drone Traffic Management (MD to add)	The drone equivalent of Air Traffic Management as we call the system for manned aviation. In Europe we call this U-space. The term UTM is also commonly used.	(CORUS) Concept of Operations for U-space [21]
European UAS Standards Coordination Group (EUSCG)	The EUSCG is a joint coordination and advisory group established to coordinate the UAS-related standardisation activities across Europe, essentially stemming from EU regulations and EASA rulemaking initiatives.	European ATM Master Plan: roadmap for the safe integration of drones into all classes of airspace.
EVLOS	An operation in which the drone pilot is supported by one or more observers, and in which the remote crew maintains direct unaided visual contact with the remotely piloted aircraft.	EASA NPA 2017-05
Geo-fence	A geographical fence or "geo-fence" is a two-dimensional virtual boundary defined by geographical coordinates that divides a real world volume in two parts.	EASA/NAA Task Force Report: Study and Recommendations regarding Unmanned Aircraft System Geo-Limitations
Geo-fencing	Function to make a UAS comply automatically with one or more geo-limitations based on geo-fences. The function can be implemented only in the UAS or distributed between the UAS and an external system (e.g. UTM system).	EASA/NAA Task Force Report: Study and Recommendations regarding Unmanned Aircraft System Geo-Limitations
Remotely piloted aircraft system	RPA are a subset of UA. A further subset of RPA is expected to be accommodated and ultimately integrated into the airspace for international, instrument flight rules (IFR) operations, which will require full regulatory certification.	ICAO Unmanned Aviation Bulletin 2018/1
Small UA/ Drones	Generally weighing less than 25 kg, this subset of smaller UA is commonly referred to as drones.	ICAO Unmanned Aviation Bulletin 2018/1
Technology Readiness Level 7 (TRL7)	System demonstration in an operational environment (ground, airborne or space): System demonstration in operational environment. System is at or near scale of the operational	SESAR 2020 Project Handbook

	system, with most functions available for demonstration and test and with EASA proof of concept authorisation if necessary. Well integrated with collateral and ancillary systems, although limited documentation available. In the context of SESAR, a TRL7 gate considers the contribution of the demonstration activities towards industrialisation and deployment.	
Unmanned aircraft	Unmanned aircraft (UA) operate as part of an unmanned aircraft system (UAS) which also includes a remote pilot station (RPS), a C2 Link for control and management, and other necessary components. UA includes a broad spectrum of aircraft, from drones, unmanned free balloons, and model aircraft, to highly complex remotely piloted aircraft (RPA) operated by licensed aviation professionals.	ICAO Unmanned Aviation Bulletin 2018/1
UAS traffic management (UTM) system	The UTM system is a concrete technical implementation comprising software, the necessary infrastructure for running the software, and the drones themselves all contributing to the achievement of UTM.	UAS Traffic Management Architecture (GUTMA)
U-space	U-space is a set of new services relying on a high level of digitalisation and automation of functions and specific procedures designed to support safe, efficient and secure access to airspace for large number of drones. As such, U-space is an enabling framework designed to facilitate any kind of routine mission, in all classes of airspace and all types of environment – even the most congested – while addressing an appropriate interface with manned aviation and air traffic control / ATC.	European ATM Master Plan: Roadmap for the safe integration of drones into all classes of airspace
Very low level	A UA operation below the height of 500 feet above ground level (AGL) or other current minimum flight height.	JARUS glossary
VLOS	An operation in which the UAS operator maintains direct unaided visual contact with the remotely piloted aircraft.	Manual on remotely piloted aircraft systems (ICAO Doc. 10019)

Table 1 - Glossary of terms

2.6 List of Acronyms

Acronym	Definition
ACC	Area Control Centre
ADS-B	Automatic Dependent Surveillance – Broadcast
AFIS	Aerodrome Flight Information Service
AGL	Above Ground Level
ANSP	Air Navigation Services Provider
APN	Access Point Name
ARTAS	ATM suRveillance Tracker and Server
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
BLIP	Broadcast Location and Identity Platform (Unifly tracker product)
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CAA	Civil Aviation Authority
CONOPS	Concept of Operations
CORUS	Concept of Operations for European UTM Systems
CR	Change Request
CTR	Control Zone
CWP	Controller Working Position
DAA	Detect And Avoid
DEMOP	Demonstration Plan
DEMOR	Demonstration Report
DTM	Drone Traffic Management
EASA	European Aviation Safety Agency
EATMA	European ATM Architecture
EC	European Commission
EOCVM	European Operational Concept Validation Methodology
EUSCG	European UAS Standards Coordination Group
EVLOS	Extended Visual Line of Sight
FIS	Flight Information Service

FIZ	Flight Information Zone
GCS	Ground Control Station
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GSM	Global System for Mobile Communications
HMI	Human Machine Interface
HPAR	Human Performance Assessment Report
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
INTEROP	Interoperability Requirements
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
KPA	Key Performance Area
MS(s)	Member State(s)
NAA	National Aviation Authority
NOTAM	Notice to Airmen
NSA	National Supervisory Authority
OI	Operational Improvement
OSED	Operational Service and Environment Definition
PODIUM	Proving Operations of Drones with Initial UTM
R&D	Research and Development
RPAS	Remotely Piloted Aircraft System
PAR	Performance Assessment Report
QoS	Quality of Service
RIO	Risks, Issues and Opportunities
SAC	Safety Criteria
SAR	Safety Assessment Report
SecAR	Security Assessment Report
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SORA	Specific Operations Risk Assessment
SPR	Safety and Performance Requirements
SWIM	System Wide Information Model
TIZ	Traffic Information Zone

TRL	Technology Readiness Level
TS	Technical Specification
UAV	Unmanned Aircraft Vehicle
UAS	Unmanned Aircraft System
UNB	Ultra Narrow Band
UTM	UAS Traffic Management
VFR	Visual Flight Rules
VLD	Very Large Demonstration
VLL	Very Low Level
VLOS	Visual Line of Sight

Table 2 - List of acronyms

3 Context of the Demonstration

This section provides the general background for the demonstration report, and describes the context for the results and the conclusions and recommendations detailed in section 4 and section 5 respectively.

3.1 U-space services and capabilities: a summary

Table 3 and Table 4 describe the services and capabilities used in the PODIUM demonstrations at the sites, in line with the descriptions in the PODIUM Concept and Architecture Description [18].

Please note that the services and capabilities that have been defined, developed, demonstrated and validated in PODIUM are slightly different from the ones described in the CORUS Conops [21] and the EASA draft opinion [22]. Please refer to Appendix E for a mapping of the PODIUM services to those described in the CORUS Conops.

	Assumed or addressed	**Odense**	**Brétigny**	**Rodez**	**Marknesse/ Eelde**
Service					
E-registration (9.2.1) (U1)	Addressed	X	X	X	X
E-identification (9.2.1) (U1)	Addressed	X	X	X	X
Drone location surveillance and tracking (9.2.2) (U2)	Addressed	X	X	X	X
Automatic flight plan validation (9.2.3) (U2)	Addressed	X	X	X	P
Automatic and manual flight permissions (9.2.4) (U2)	Addressed	X	X	X	X
Generation and management of no-fly zones those become active while the drone is in flight (9.2.5, 9.2.7, 9.2.8) (U2)	Addressed	X	X	_	X
Generation and management of no-fly zones based on aeronautical information (including NOTAMs) and aviation regulations (9.2.7) (U2)	Addressed	X	X	_	X
Conflict Detection / Alerting (9.2.14) (U2)	Addressed	X	X	_	P
Post-flight services/legal	Addressed	X	_	X	X

	Assumed or addressed	Odense	Brétigny	Rodez	Marknesse/ Eelde
Service					
recorder (9.2.12)					
ATC collaborative interface (Appendix D) (U3)	Addressed	_	_	X	X

Table 3 - U-space services used at the PODIUM sites

	Odense	Brétigny	Rodez	Marknesse/ Eelde
System				
Drones				
• Fixed Wing	X	X	X	X
• Multi-rotor	X	X	_	X
• Helicopter	_	_	_	_
• General aviation	X	_	X	_
UNIFLY system populated with airspace info. and drone regulations, etc.				
• UNIFLY Sentry (authorities/regulators/ATCOs)	X	X	X	X
• UNIFLY Pro (drone operators)	X	X	X	X
• UNIFLY Launchpad/handheld (drone operator)	X	X	_	_
Airbus System				
• RT Data Collector (U-space surveillance Tracker And Server)	X	X	X	X
• RT CWP	_	_	X	-
• Cooperative tracking	X	X	X	X
• Non-cooperative tracking	_	_	_	-
• Recording (U2)	X	X	X	X
• Integration with UNIFLY UTM system	X	X	X	X
• Orange Access Point Name (GSM connectivity)	X	X	X	X

	Odense	Brétigny	Rodez	Marknesse/ Eelde
System				
Tracker				
• Hionos (GSM)	_	X	_	_
• DroneID (GSM)	X	_	_	_
• Airbus identifier and tracker (UNB L-band)	_	_	X	_
• uAvionix (ADS-B, 1090 MHz)	_	_	_	X
• Delair Tech (GSM)	_	_	X	_
• ARTAS	*	_	P	_
• Other; uAvionix Ping Station	_	_	_	X

Table 4 - Systems used at the PODIUM sites

*See deviations at paragraph 3.3 .

3.2 Summary of the Study Plan

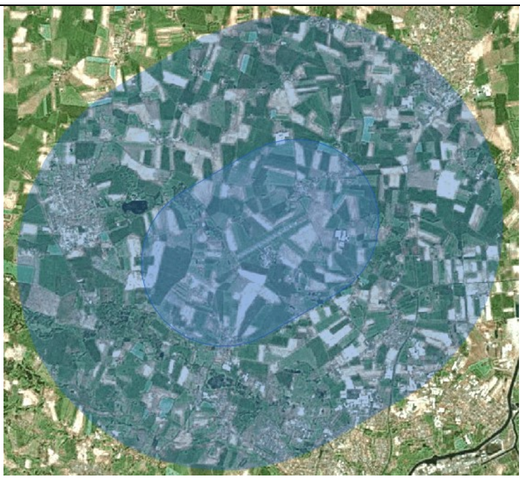
3.2.1 VLD Purpose and approach

Purpose

The overall aims of the PODIUM VLD are to:

- Demonstrate U-space services, procedures and technologies (U1, U2 and partial U3) at five operational sites at Odense in Denmark, Brétigny and Rodez in France, and the Netherlands RPAS Test Center and Groningen Airport Eelde in the Netherlands throughout 2018 and 2019;
- Provide agreed conclusions on the maturity of U-space services and technologies with respect to TRL7 – backed up by evidence on efficiency, safety, security and human performance metrics etc. – when used for a defined set of operational scenarios and environments;
- Provide recommendations on future deployment and for regulations and standards.

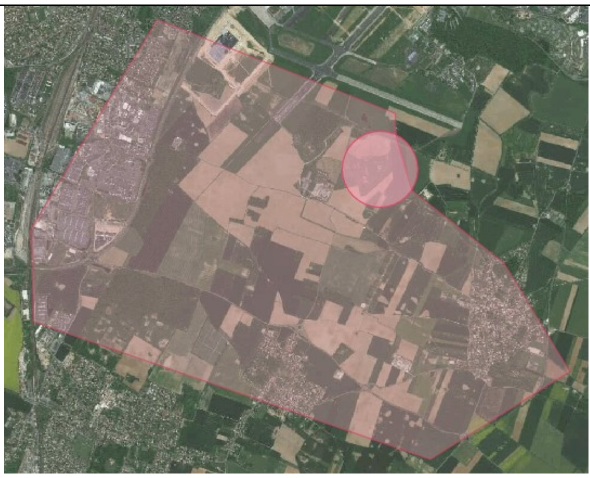
The PODIUM demonstrations were performed at five operational sites as shown below.



Odense

The airspace used covered the VLL part encompassing airspace class G, traffic information zone (EKOD TIZ), and rural and urban areas (vicinity of Odense city). The area used corresponds essentially to the dedicated airspace already attached to the UAS Test Center in Odense at Hans Christian Andersen airport. The airspace used for the demonstrations is shared by fixed wing and helicopter flights which operate on a daily basis around Odense.

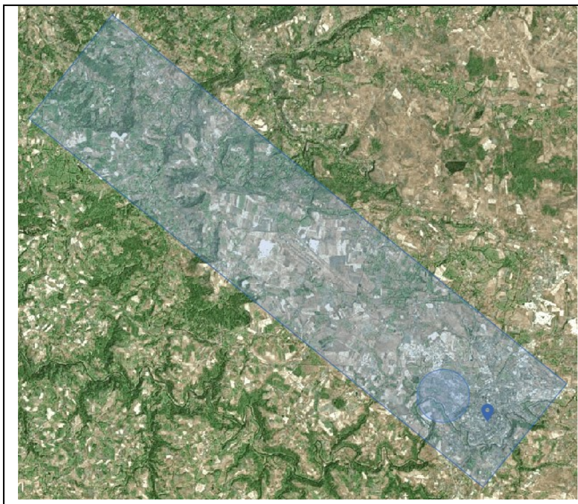
Figure 1 Odense



Brétigny

The LF R 333 Bretigny Leudeville is a drone dedicated flight zone (ZR). It is located on the grounds of a former air force base and flight test center: BA 217 (Base Aérienne 217). It is 300 ha wide and maximum altitude is 150 m. Drones Paris Region manages the airspace. Since Orly Airport is nearby, a protocol has been signed between Drones Paris Region and French DGAC to define rules of operations. A similar protocol is signed between Drones Paris Region and each operator that comes to fly in the zone. VLOS and BVLOS operations are conducted in the zone.

Figure 2 – Brétigny



Rodez

The Rodez demonstration addresses BVLOS flights in the vicinity of and in the Class D CTR of the airport of Rodez-Aveyron (LFCR) in the south west of France, allowing to: perform BVLOS flights transiting through various controlled or restricted airspaces; and perform a long duration flight within a tower controlled area (implying multiple interactions during the flight with the same authority).

Figure 3 – Rodez

	<u>Groningen Airport Eelde</u> Drone flights were conducted at Groningen Airport Eelde Airport and at the Netherlands RPAS Test Centre. The airspace around Eelde Airport is a class C CTR that extends up to 3000ft. All drone missions will be executed within the Eelde CTR. Eelde airport has a two runways (23/05 and 01/19), and is equipped with facilities for IFR with VOR, NDB, RNAV, ILS approaches. The airport is used by low-cost air carriers and general aviation

Figure 4 - Groningen Airport Eelde

	<u>Netherlands RPAS Test Centre, Marknesse</u> The Netherlands RPAS Test Centre has the ability to perform test flights with (experimental) RPAS (drones); to perform sensor tests and evaluations; to carry out training flights with RPAS under the supervision of a flight instructor; to perform RPAS flight examination. NLR has been granted all required accreditations and exemptions to facilitate these activities. Drone flights were conducted in uncontrolled airspace in a rural area at the Netherlands RPAS Test Centre.

Figure 5 - Netherlands RPAS Test Centre, Marknesse

Approach

The demonstrations took place in Odense, Denmark; in Rodez and Brétigny, France; and in the Netherlands RPAS Test Centre Marknesse and Groningen Airport Eelde. Each of these five sites has its own specificities. The demonstrations enabled the PODIUM U-space services, procedures and technologies to be used "hands on" by drone operators, ATCOs and supervisors, and for many types of drone operations (e.g. electricity line inspection, emergency services, deliveries).

The PODIUM solution at the sites has been verified and implemented in accordance with the PODIUM Availability Note [20].

Together the five sites demonstrations have ensured a thorough demonstration of the potential and technology readiness level (TRL) of the PODIUM U-space services, procedures and technologies.

Data collection and analysis

The PODIUM Common Metrics Development document [25] describes the data collection and analysis method used in the demonstrations. The demonstrations assessed the objectives and success criteria (3.2.3) using a mixture of qualitative and quantitative data.

The project collected the following qualitative data:

- 41 completed post demonstration questionnaires (some in an electronic format);
- Observations from the EUROCONTROL validation experts present and from project members in general;
- Post exercise de-briefings in the presence of a facilitator with all involved partners/stakeholders/actors:
    - To share views and consolidate results;
    - Structured around early results and feedback.

The project obtained some quantitative data collection through recordings from the trackers/communications means (e.g. 3D drone positions along time, latency of exchanges) and logs from the UNIFLY, Airbus and Orange systems.

Subsequently, an analysis of the qualitative and quantitative data collected has been performed, the results of which are described at section 4.

Considering the variety of scenario, site, local regulations and standards, technological developments (UNIFLY, Airbus, trackers….), no inferential statistical analysis (e.g. statistical tests) has been performed. As a result, the quantitative analysis should only be considered as initial trends.

3.2.2 Operating method description

As indicated in Figure 6, the U-space vision implies a number of paradigm changes compared to air traffic management today. One significant change relates to the role of the human. Faced with the foreseen increases in the density and complexity of drone traffic [28], increased automation and a reduced "human in the loop" element can be foreseen. A second change relates to the enabling infrastructure. Whereas the existing CNS-ATM infrastructure has been designed to cope with manned aviation traffic, it would not be compatible with significant drone traffic in VLL airspace. Hence, U-space foresees the use of complementary infrastructures, like mobile phone networks, to support tracking and thus situational awareness.

This section elaborates on two key drivers for U-space – namely overcoming 'see & avoid' and manual process limitations – before introducing the PODIUM Concept used in the demonstrations.

Figure 6 PODIUM U-space vision

See and Avoid limitations

As long as drones are operated as VLOS, the drone pilot can remain clear of other traffic based on the see and avoid principle. The application of the see and avoid principle to detect small drones is very challenging, however, both now and increasingly in the future:

- With the development of drones with greater operating ranges, BVLOS operations are possible
- The increase of VLL drone traffic increases the risk of collision
- The usage of small drones close to airports has led to incidents with IFR traffic

To ensure an equivalent level of manned aviation safety, additional means for drone operations are required.

Manual processes limitations

"For a typical mission, 70% percent of our effort goes into getting the flight authorisation!" was the view expressed by one drone operator at Brétigny. Today a number of manual processes need to be performed before a drone operator can actually fly an operation. For example:

- Flight applications often require documents to be completed and sent by email, often requiring approvals from many different parties.
- Extensive searches are required to confirm that drones can fly at a particular location and time, taking into account airspace restrictions etc.
- Voice communication with ATC, the police and other parties are performed by phone, which can lead to additional workload, delays and even missed information (e.g. a supervisor makes an urgent call to a drone pilot but the mobile phone is engaged)

All this takes time and effort which can impact the commercial viability of certain drone operations.

PODIUM Concept

The concept that is underlying the PODIUM project is primarily an automated, secure web-based Business to Business (B2B) service, proposed to each stakeholder involved in drone operations, in order for them to accomplish their mission safely and efficiently. This type of U-space service enables each actor to access the information to complete his/her business and duty in the most efficient way.

Using the U-space services and capabilities listed at section 3.1, the scenarios performed in the demonstrations address: before operation, mission preparation, mission execution and post-flight phases:

- Before operation: this will consist in performing e-registration and e-identification;
- Mission preparation: fleet management, briefing, flight planning, flight approval and authorizations, capacity management, weather forecast analysis, Aeronautical data handling, national and local legislation data handling, notification and approval of operations in no-fly-zones, and geo-fencing;
- Mission execution: provision of static and dynamic data as airspace information, meteorological data, terrain, geo-fencing and visualization of legislation for all drone operators based on GIS data and the Unifly rule engine. It also covered the interface with ATM/ATC;
- Post-flight: It consists of recording and playback the mission in order to support analysis of collected technical and operational data in order to evaluate the results obtained in the two first phases, identify problems encountered and positive elements.

Roles

Please refer to section 7 of the PODIUM Concept & Architecture description [18] for a description of the roles and responsibilities applicable to PODIUM.

For the purposes of this demonstration report, the following roles are highlighted:

- The supervisor role (not to be confused with the ATCO supervisor role) has been performed for the demonstrations at Hans Christian Andersen airport, Odense; the Netherlands RPAS Test Centre, Marknesse; and the Drone Paris Region cluster, Brétigny-sur-Orge. The supervisor's responsibilities include:
    - Ensuring that the drone operator has the registrations, etc. required for the planned operations;
    - Granting flight permissions in the area of his/her area of responsibility;
    - Monitoring drone operations in his/her area of responsibility.
- The air traffic controller (ATCO) role has been performed at the towers of Groningen Airport Eelde and Rodez-Aveyron airport, with the normal responsibilities of providing instructions and/or clearances, etc.
- The drone operator role is the legal entity accountable for all the drone operations it performs; responsible for managing a fleet and/or monitoring the drone(s) when in flight. In practice, the term drone operator and drone pilot are often equivalent in this demonstration report.

PODIUM Architecture

The architecture design used for the PODIUM demonstrations is shown at Figure 7. This architecture has been adapted for each of the sites, to take into account local specificities such as the type of tracker used. Orange provided their access point name (APN) connectivity, roaming and firewall solutions to enable tracker information to be securely transported from the demonstration sites to the UTM systems managed from Airbus in Toulouse and Unifly in Antwerp.

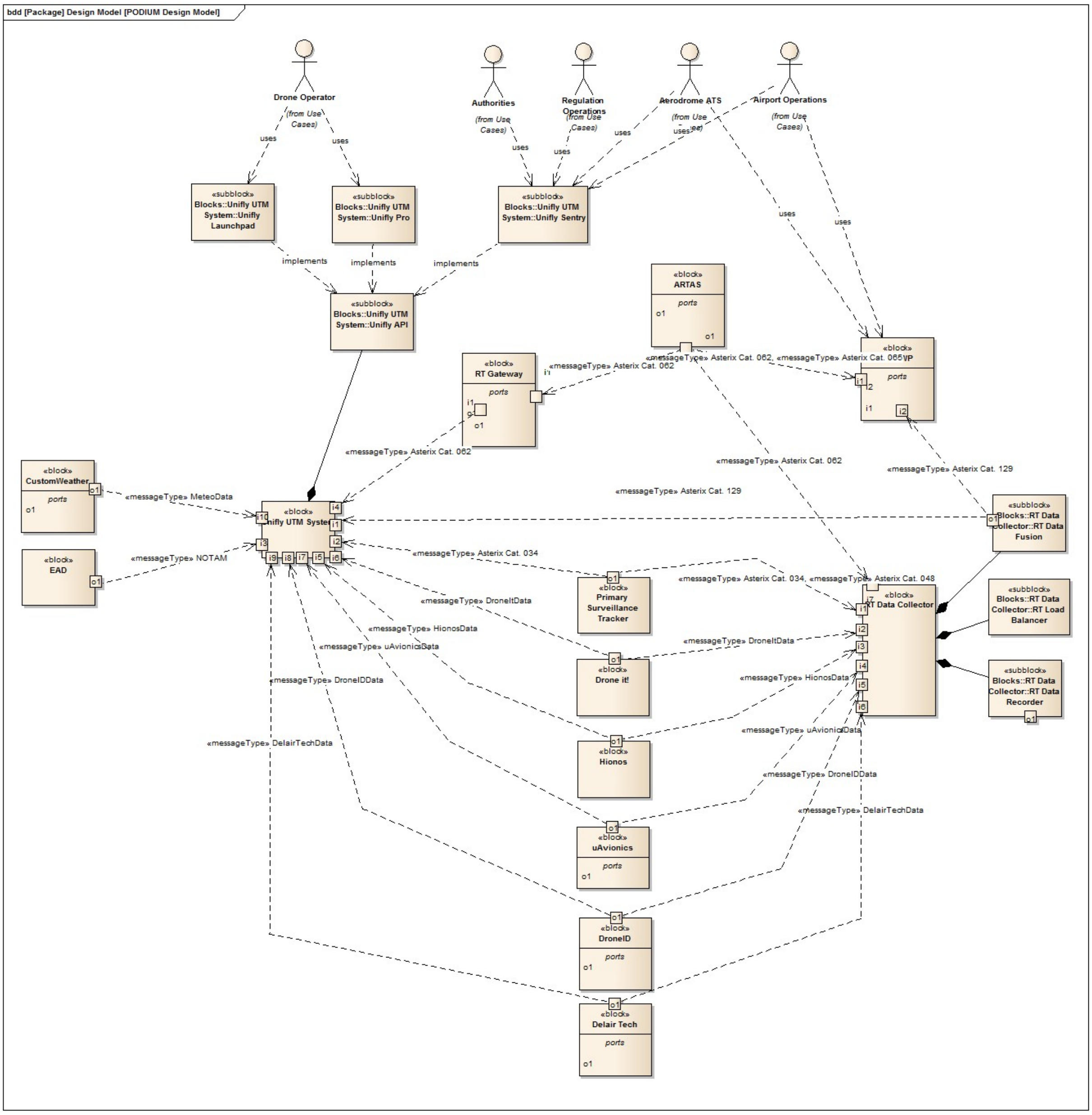


Figure 7 - Generic architecture

Technology environment

The main elements of the technology environment used for the PODIUM demonstrations are:

- The PODIUM U-space cloud which provides a shared pool of services and data, accessible via web-based services and SWIM including:
  - The UNIFLY system populated with airspace data, regulations etc.
  - The Airbus system comprising RT Data Collector, Controller Working Position, etc.
- The PODIUM U-space application interfaces including:
  - Smartphone application with visualised fly and no-fly zones
  - Web-based application supporting communications and requests for authorisations
  - U-space service provider application supporting management services such as the creation of prohibited and restricted drone zones
  - Open API application allowing very large drone operators to connect via their own HMI
- Trackers:
  - uAvionix transmits on the Mode-S ES (1090 MHz) transponder radio band;
  - "Drone Identifier and Tracker" transmits in the L-Band to a dedicated network;
  - Hionos (GSM based)
  - Delair Tech (GSM based)
  - SDU DroneID (GSM based)
- Network coverage:
  - GSM (including Orange access point name connectivity solution, roaming and firewalls)
  - 1090 MHz for ADS-B
  - UNB-L-band
- Drones
  - Multi-rotor
  - Fixed-wing

3.2.3 Summary of Study Objectives and success criteria

Table 5 shows the list of project level demonstration objectives and criterion taken from the Revised Demonstration Plan [17]. The objectives and criterion are further elaborated at site level as shown in the site demonstration reports [30], [31], [32] and [33].

Identifier	**OBJ-VLD-PODIUM-001**
Title	**Operational feasibility and acceptability** of U-space services
Objective	To demonstrate the impact on human performances through assessment of operational feasibility and acceptability of U-space services addressed (U1, U2 and initial U3), in key environment conditions
Category	<operational feasibility>, <acceptability>, <human performance>,
Key environment conditions	Nominal, various flight rules (VLOS, BVLOS, VFR, IFR), various environment (suburban, rural environment, within CTR).
Identifier	**Success Criterion**
CRT-VLD-POD-001-	The roles and responsibilities of the involved actors (individual and at the level

001	of the team) are clear and acceptable under U-space services addressed (U1, U2 and initial U3).
CRT-VLD-POD-001-002	The tasks and procedures of the involved actors (individual and at the level of the team) are clear and acceptable under U-space services (U1, U2 and initial U3).
CRT-VLD-POD-001-003	The technical systems proposed are usable (HMI) and acceptable (e.g. trust in the systems, limitation of human errors) to end users for tested U-space services (U1, U2 and initial U3).
CRT-VLD-POD-001-004	The technical systems proposed support the end users' performance in order to achieve their tasks in an efficient, accurate and timely manner for tested U-space services (U1, U2 and initial U3).
CRT-VLD-POD-001-005	The communication load and phraseology associated to U-space services (U1, U2 and initial U3) are acceptable.
CRT-VLD-POD-001-006	The training and transition needs associated to U-space services (U1, U2 and initial U3) are identified and documented for all future users
Identifier	**OBJ-VLD-POD-002**
Title	**Technical feasibility** of the various systems (e.g. trackers, Unifly UTM system, Airbus systems)
Objective	To demonstrate that the various technical systems supporting U-space services addressed (U1, U2 and initial U3) meet critical functional and performance requirements.
Category	<technical feasibility>, <interoperability>, <safety>, <security>
Key environment conditions	Nominal, various flight rules (VLOS, BVLOS, VFR, IFR), various environment (suburban, rural environment, within CTR).
Identifier	**Success Criterion**
CRT-VLD-POD-002-001	The various systems provide the information required for U-space services (U1, U2 and initial U3) as it is needed and when it is needed
CRT-VLD-POD-002-002	The various systems perform as expected even when used to supervise simultaneously multiple drones (by a single or by multiple drone pilots)
CRT-VLD-POD-002-003	The various infrastructures support U-space services addressed (U1, U2 and initial U3)
CRT-VLD-POD-002-004	The various systems are interoperable enough for the end users to provide expected benefit.
Identifier	**OBJ-VLD-PODIUM-003**
Title	**Safety** of U-space services
Objective	To demonstrate that U-space services addressed (U1, U2 and initial U3) can be safely performed in key environment conditions
Category	<performance>, <safety>, <human performance>
Key environment conditions	Nominal, various flight rules (VLOS, BVLOS, VFR, IFR), various environment (suburban, rural environment, within CTR).
Identifier	**Success Criterion**
CRT-VLD-POD-003-001	Demonstrate the safe integration of drones from pre-flight to post flights, through increased awareness of all airspace users, strategic deconfliction and conformance monitoring
CRT-VLD-POD-003-002	Demonstrate that the U-space services addressed (U1, U2 and initial U3) contribute to the limitation of air risk in VLL airspace

CRT-VLD-POD-003-003	Demonstrate that the U-space services addressed (U1, U2 and initial U3) contribute to the limitation of ground risk
CRT-VLD-POD-003-004	Demonstrate that the U-space services addressed (U1, U2 and initial U3) contribute to the limitation of incursion into no-drone zones nearby the VLL airspace
Identifier	**OBJ-VLD-PODIUM-004**
Title	**Security** of U-space services
Objective	To demonstrate that U-space services addressed (U1, U2 and initial U3) can be securely performed in key environment conditions
Category	<performance>, <security>
Key environment conditions	Nominal, various flight rules (VLOS, BVLOS, VFR, IFR), various environment (suburban, rural environment, within CTR).
Identifier	**Success Criterion**
CRT-VLD-POD-004-001	Demonstrate that the resilience of U-space services addressed (U1, U2 and initial U3) is in line with the business and safety requirements
CRT-VLD-POD-004-002	Demonstrate that U-space services addressed (U1, U2 and initial U3) provide the means to sufficiently prevent abuse of drone operations for malignant purposes.
Identifier	**OBJ-VLD-PODIUM-005**
Title	Standards and regulation of U-space
Objective	To document the impact of U-space services addressed and on **standards and regulations** in key environment conditions
Category	<standards and regulation>
Key environment conditions	Nominal, various flight rules (VLOS, BVLOS, VFR, IFR), various environment (suburban, rural environment, within CTR).
Identifier	**Success Criterion**
CRT-VLD-POD-005-001	The impact of U-space services addressed (U1, U2 and initial U3) on operational or technical standards (creation or changes of existing ones) is documented
CRT-VLD-POD-005-002	The impact of U-space services addressed (U1, U2 and initial U3) on regulations (compatibility with or need for change) is documented
Identifier	**OBJ-VLD-PODIUM-006**
Title	**Initial benefits assessment** of U-space services
Objective	To collect initial feedback from the different stakeholders on the benefits/limitations of the U-space services addressed (U1, U2 and initial U3) in various situations
Category	<cost-effectiveness>,<capacity>
Key environment conditions	Nominal, various flight rules (VLOS, BVLOS, VFR, IFR), various environment (suburban, rural environment, within CTR).
Identifier	**Success Criterion**
CRT-VLD-POD-006-001	Initial benefits and limitations of the U-space services addressed (U1, U2 and initial U3) in terms of cost effectiveness t(e.g. potential time, effort, cost saving) are identified
CRT-VLD-POD-006-002	Initial benefits and limitations of the U-space services addressed (U1, U2 and initial U3) in terms of capacity (e.g. potential for enabling more simultaneous

	flights)

Table 5 - Objectives and Criterion

3.2.4 Study Assumptions

Table 6 shows the assumptions applicable at the overall project level. Additional assumptions at the site level are captured the site demonstration reports [30], [31], [32] and [33].

Identifier	Title	Description
POD-A1	BVLOS procedures	BVLOS procedures are in place
POD-A2	BVLOS approvals	BVLOS operations are approved by the NAA
POD-A3	Tracker compatibility with drone	The tracker configurations are compatible with the drones (weight, dimensions, power consumption etc.).
POD-A4	Tracker compatibility with U-space	The Trackers are available (DELAIR, Unifly) and integrated to the Unifly technical Platform (identification, drone and user registration, GNSS position).
POD-A5	Airspace users	Airspace users are fully involved to support demonstrations requiring cooperation between manned and unmanned flights.
POD-A6	Drone flight route design	The routes and procedures for drone operations are appropriately designed and approved by all relevant authorities (overflight, distance form building, etc.)
POD-A7	Airport procedures	Airport coordination procedures are validated.
POD-A8	Manned aircraft	UTM hardware can be installed on manned aircraft participating in the demonstrations.
POD-A9	Baseline U-space documents	In the absence of suitable baseline documents on U-space, the PODIUM Concept & Architecture document from WP02 can be used as the operational and technical baseline for the document
POD-A10	Drone pilot and operator availability	Drone operators and pilots are available to perform the flights
POD-A11	U-space platform available	The Unifly Platform is available and instantiable in the frame of the demonstrations.
POD-A12	ATC available	ATC is available to participate in the trials

Table 6 - Assumptions

3.2.5 Demonstration Exercises List

Table 7 shows the full set of exercises and scenarios performed at the sites, and detailed descriptions are available in the Revised Demonstration Plan [17]. Table 8 shows the allocation of the demonstration objectives to the exercises.

Exercise and Scenario ID	Exercise and Scenario Title
EXE-VLD-ODE-001 (Odense)	**Enhancing drone interface with aviation environment**
EXE-VLD-ODE-001 – Scenario 1	Fixed wing inspection flights in VLOS and BVLOS
EXE-VLD-ODE-001 – Scenario 2	Parcel delivery flights in VLOS and BVLOS
EXE-VLD-ODE-001 – Scenario 3	Multirotor UAV's operations for airport fence or infrastructural inspection in VLOS and EVLOS
EXE-VLD-ODE-001 – Scenario 4	Operations in rural and simulated urban areas within Odense FIZ and restriction zone EK R OD1 in VLOS
EXE-VLD-ODE-001 – Scenario 5	Firefighting and police operations in rural and urban areas in VLOS
EXE-VLD-BRE-002 (Brétigny)	**Enhancing Business Operations with UTM Services**
EXE-VLD-BRE-002 – Scenario 1	Usage of Fixed wings and Multirotor drone for specific industrial applications – VLOS
EXE-VLD-BRE-002 – Scenario 2	Usage of fixed wings and multirotor drones for site surveillance – VLOS
EXE-VLD-BRE-002 – Scenario 3	Interaction of UTM with anti-drones systems
EXE-VLD-BRE-002 – Scenario 4	UTM services enhancement w respect to new operational technologies
EXE-VLD-BRE-002 – Scenario 5	Usage of Fixed wings drones for surveillance - BVLOS
EXE-VLD-TOU-003 (Rodez)	**BVLOS flights entering and exiting a CLASS D CTR**
EXE-VLD-TOU-003 – Scenario 1	Take-off within the CTR, exiting the CTR and flying back into the CTR
EXE-VLD-TOU-003 – Scenario 2	Take-off within the CTR, exiting the CTR and flying back into the CTR, finally C2 link loss
EXE-VLD-TOU-003 – Scenario 3	Take-off within the CTR, DT18 flying off planned route
EXE-VLD-TOU-003 – Scenario 4	Take-off out of the CTR, entering the CTR and ATCO re-routing the drone
EXE-VLD-TOU-003 – Scenario 5	Take-off out of the CTR, entering the CTR and pilot declaring inability to complete the mission
EXE-VLD-EEL-004 (Marknesse & Eelde)	**The 'Unexpected' scenarios**

EXE-VLD-EEL-004 – Scenario 1	Drone flight execution based on mission priority
EXE-VLD-EEL-004 – Scenario 2	Update of mission plan during flight while considering surrounding drones
EXE-VLD-EEL-004 – Scenario 3	Update of mission plan following ATC instructions

Table 7 - Exercise and scenario list for all PODIUM locations

Exercise ID	OBJ-VLD-POD-001 Operational feasibility and acceptability	OBJ-VLD-POD-002 Technical feasibility	OBJ-VLD-POD-003 Safety	OBJ-VLD-POD-004 Security	OBJ-VLD-POD-005 Standard & regulations	OBJ-VLD-POD-006 Initial benefits assessment
EXE-VLD-ODE-001	X	X	X		X	X
EXE-VLD-BRE-002	X	X	X	X	X	X
EXE-VLD-TOU-003	X	X	X		X	X
EXE-VLD-EEL-004	X	X	X	X	X	X

Table 8 - Allocation of objectives to exercises

3.3 Deviations with respect to the Demo Plan

The main deviations between the planned activities in the Revised Demonstration Plan [17] and the actual activities are now described. It is important to note that a number of these deviations are very relevant to the challenges faced by drone operators on a day-to-day basis, and hence their applicability goes way beyond PODIUM, e.g. delayed operations due to bad weather.

Deviation: late feature availability compared to product roadmap

The full set of planned U-space/UTM features was not available for some of the early flights, including: supervisor flight permission feature; Unifly launchpad (handheld..

It is essential to keep in mind that the UTM features used in PODIUM where delivered in line with the product roadmap of the partners, and not as “one-off” solutions to support a “showcase” demonstration on a particular day. The latter approach could have resulted in expensive, “rushed” solutions that were not reusable at a later date. As a consequence, the timing of some feature deliveries was later than the slots planned for the PODIUM activities on the sites.

The lack of features was mitigated by manual procedures including the use of R/T. In practice, the UTM system supported enough features to enable the participants to provide feedback on the current state of the art for U-space/UTM systems as well as expectations for the future.

Deviation: reduced number of flights

The number of actual flights performed using the U-space/UTM system was less than originally planned. The partners cited a number of reasons the reduced number of flights:

- Integra explained that the time taken for training, mission preparation, questionnaire completion and debriefings was longer than originally planned, and this reduced the time available for actual flights;
- NLR explained that the original estimated number of flights included some flights for contingency in case of interruptions due to technical problems or bad weather, which were not needed in practice;
- DPR explained that they focussed their efforts on the flight preparation phase, but still performed enough flights to validate the available functionality for the flight execution phase . Moreover, the UTM system was not used on a day-to-day basis at Brétigny as originally expected by DPR. This was due to the fact that the tool, although suitable for demonstration purposes, was not configured for day-to-day business operations requiring coordination with authorities, etc.

In actual fact, all partners across the sites have confirmed that they were able to perform a sufficient number of flights and flight authorisation workflowsfor the purposes of data collection and analysis.

Deviation: Delays due to weather

A number of demonstration flights at Odense and Brétigny had to be postponed due to bad weather. For example, on one occasion the average wind speed at Odense was 9 m/s but with gusts of 15 m/s, and hence it was assessed to be too risky to perform the demonstrations. The postponements due to weather led to significant logistical challenges – including the availability of drone operators - to perform the flights at a later date.

Deviation: BVLOS approvals

The project performed one and not two BVLOS flights at Odense as originally planned. Since Integra did not get their BVLOS approval in time, they took the decision for Southern Denmark University – who already had BVLOS approvals – to perform a BVLOS flight with the Sky-Watch Cumulus 4. In actual fact, the decision to involve SDU was a positive one, as it gave the opportunity for an additional drone operator (experienced in BVLOS flights) to provide their feedback on the UTM system.

At Groningen Airport Eelde, The BVLOS procedures were in place but needed fine-tuning during the practice day. A total of 4 crew members were needed. One (indoor) BVLOS pilot, one (outdoor) safety VLOS pilot, one observer and one test coordinator. The test coordinator was added to manage the demonstration's timing and sequencing and performed the R/T communications with Eelde tower. Although the fourth crew member was needed, his presence complicated the communication procedures among the crew members, and it would be preferred if the other crewmembers could communicate with ATC and a three-man crew would suffice for normal operations.

Deviation: ARTAS not used

The project planned to use the ARTAS system to establish an air situation picture of manned and unmanned traffic at Odense. In practice, the ARTAS system was not used at Odense for the following reasons:

- During the planning phase: uncertainty about the Asterix category to be used by each drone position sensor; uncertainty about how EU/EASA would prescribe the drones remote ID; different perceptions about where and how tracking for UTM and ATM should take place. Due to this uncertainty, it was not possible to test the functionality of ARTAS using actual drone inputs.

- GDPR-issue related to the ARTAS problems. During the planning period an unexpected event happened as CPH airport was involved in a dispute where a lawyer objected to the public display of his own private airplane's flight registration on a webpage. As the airplane is fully owned by one single person then using the registration is thereby identifying him as a person. This case has now been settled. It became evident that Naviair needed to do something extra to ensure that its role as service provider (data owner) was compliant with GDPR. This work is still going on.

- ARTAS & Odense. Due to the unclear physical specification of the test setup and operational involvement of the TWR a lot of time was wasted trying to understand which (external) connection to establish between equipment in Odense Airport and the ARTAS situated in Copenhagen/Kastrup. As the ARTAS data is part of the operational ATM then it is not easy to get online data out of the highly encapsulated environment for cybersecurity reasons. Odense Airport is not serviced by Naviair and there were therefore no network connections available beforehand.

Naviair expects tracks to be sent through a shared surveillance system, i.e. that all UTM sensors must follow the normal EU regulations and provide the output in a standard Asterix-format. The importance of using the same Surveillance system is that we need to ensure that all users (drone operators, pilots, ATCOs, Police, etc.) operates using the exact same air situation picture. The UTM system must thus accept the Asterix, cat. 62 as input of drone & other aircraft positions from the shared Surveillance system.

At Rodez, the DTI system was used to provide ATM tracks from manned aviation. Moreover, a local ADS-B receiver was set up to obtain an additional source of ATM tracks.

Deviation: lack of direct communication between U-space system and controllers

For the "unexpected" scenarios at Groningen Airport Eelde, NLR planned to use the U-space system for direct communications between the pilots and controllers, e.g. for ATC to instruct the drone pilot to divert to another runway. In practice, there were instances when using the U-space system was too slow and so direct R/T communications were needed instead. NLR concludes that, within a controlled environment, drone pilots shall be able to respond immediately to ATC clearances, also without using the U-space system.

4 Study Results

4.1 Summary of Study Results

This section summarises the study results from two different perspectives. Firstly, Table 9 summarises the deployment readiness of each of the services compared to the demonstration objectives. This table is the result of a structured review at the PODIUM face-to-face project management team meeting held at EUROCONTROL Brussels on September 18-19 2019. Secondly, Table 10 provides a summary of the study results based on the objectives compared to flight phases.

Green : Ready for deployment assuming minor actions

Amber : Ready for deployment assuming significant actions

Red: Not ready requiring major actions

Flight phase	Service level	Service addressed	OPS feasibility	Tech feasibility	Safety	Security	Benefits	Standards and regulations	Comments/actions (including main source in brackets where appropriate)
Mission preparation	U1	E-registration (9.2.1)	Green	Amber	Green	Green	Green	Amber	• Ensure compatibility with existing national registration systems (DPR) • Require minimum standard information about drone characteristics (DPR)
		E-identification (9.2.1)	Green	Green	Green	Green	Green	Red	• Ensure link between drone registration ID and the tracker ID (Airbus) • Ensure regulations address tracker carriage

Flight phase	Service level	Service addressed	OPS feasibility	Tech feasibility	Safety	Security	Benefits	Standards and regulations	Comments/actions (including main source in brackets where appropriate)
	U2	Automatic flight plan validation (9.2.3)							• Ensure trustworthy, reliable and up-to-date aeronautical, national and local legislation data • Ensure governments provide approved data for populated areas, bridges, electrical, etc. • Ensure compatibility with ICAO flight plan for flight entering CTR (NLR)
		Automatic and manual flight permissions (9.2.4)							• Authorities require all necessary information to support their decision, e.g. other flights in the same area/time slot etc. • Adequate regulation to support automatic permission rules and the related technical implementation • Need rule-based and automated supervisor function (coping with multiple flights) • Need agreed algorithm to maintain safety in the event of multiple flights (strategic deconfliction)
		Generation and management of no-fly zones based on aeronautical information (including NOTAMs and aviation regulations (9.2.7)							• Ensure all information related to safety and other drone traffic is available to the crew • Define the NOTAMs format which are actually necessary for drone operations (applicable Q codes?) • Define the methods/responsibilities for handling NOTAMs • Ensure governments provide approved data for populated areas, bridges, electrical, etc.

Flight phase	Service level	Service addressed	OPS feasibility	Tech feasibility	Safety	Security	Benefits	Standards and regulations	Comments/actions (including main source in brackets where appropriate)
Mission execution		Drone location surveillance and tracking (9.2.2)							• Essential for drone pilots to have situational awareness of own and other traffic • Design an optimised/integrated flight crew HMI for flight controls and UTM situational awareness • Essential to establish standards for tracker performance (accuracy and availability/reliability; and integrity) and interoperability • Essential to have sufficient network coverage to handle tracker signal reception • Essential to determine the area of operation where tracking is required • Standards for low-power lightweight transponder • Assign spectrum/bandwidth/channels for tracking?
		Generation and management of no-fly zones those become active while the drone is in flight (9.2.5)							• Essential to have effective communications procedures and phraseology between drone pilots and ATCOs/supervisors to handle unexpected, sudden events that impact the drone’s flight profile (current use of mobile phones insufficient?) • Further detailed study of the concept of operations, benefits for different stakeholders, HMI, procedures, communications technical impact

Flight phase	Service level	Service addressed	OPS feasibility	Tech feasibility	Safety	Security	Benefits	Standards and regulations	Comments/actions (including main source in brackets where appropriate)
		Conflict Detection /Alerting (9.2.14)							• Essential for all concerned aircraft (drones and manned aviation in VLL) to have a tracker/transponder • Essential to determine the concept of operations, flight rules, separation requirements and the conflict detection algorithm • Essential to determine the prioritisation between the conflicting drones
	U3	ATC collaborative interface (Appendix D)							• Essential to work on the pilot HMI, communication procedures, flight crew roles • Essential to validate with different scenarios and environments • Essential to have an effective drone tracking system

Table 9 - Service readiness for deployment

Demonstration Objective (as in section 3 of Demo Plan)	Demonstration Success criteria (as in section 5 of Demo Plan)	Exercise results	Demonstration objective status (OK, NOK, POK (Partially OK))
OBJ-VLD-POD-001 Operational feasibility and acceptability	CRT-POD-001-001 CRT-POD-001-002 CRT-POD-001-003 CRT-POD-001-004	<u>Pre-flight</u> • The flight crew and ATCO/supervisors found the PODIUM U-space/UTM solution to have a high to moderate operational feasibility and acceptability level for the pre-flight phase. • Flight crew are not prepared to enter information twice into existing national systems (like the French "Alpha Tango") and a separate U-space/UTM system. They have a strong preference for	POK

Demonstration Objective (as in section 3 of Demo Plan)	Demonstration Success criteria (as in section 5 of Demo Plan)	Exercise results	Demonstration objective status (OK, NOK, POK (Partially OK))
	CRT-POD-001-005 CRT-POD-001-006	U-space/UTM systems that interact seamlessly and automatically with national systems. • Supervisor/ATCOs lacked some information to support decision making, e.g. strategic view of where other users are planning to fly.	
		<u>Flight execution</u> • The flight crew found the PODIUM U-space/UTM solution to have a negative to very negative operational feasibility and acceptability level for the flight execution phase. This was principally due to the lack of a suitable handheld device to provide situational awareness; using a laptop was deemed to be not practicable in the field. • Supervisors/ATCOs found the PODIUM U-space solution to have a very high to medium operational feasibility and acceptability level for the flight execution phase. This can be attributed to the fact that, unlike the pilots, the supervisor/ATCOs were provided with a display providing situational awareness. • The ATC collaborative interface tested in Rodez was globally found operable and acceptable by the air traffic controller supervising the drone operation. • The Marknesse demonstrations have shown that is extremely difficult for a human supervisor to respond adequately to "unexpected scenarios" involving multiple drone flights. In such cases, a rule-based and automated supervisor function is essential. • The demonstrations highlighted problems manual communication procedures and phraseology between flight crew and supervisors. In the absence of an automated messaging system, clear R/T communications procedures and phraseology are required between the pilot and air traffic controller/supervisors.	NOK
OBJ-VLD-POD-002 Technical feasibility	CRT-POD-002-001 CRT-POD-002-002 CRT-POD-002-003	<u>Pre-flight:</u> • Pilots appreciate the automatic validation of the mission according to the current regulation. They highlight the importance of having access to trustworthy aeronautical, national and local legislation data.	POK

Demonstration Objective (as in section 3 of Demo Plan)	Demonstration Success criteria (as in section 5 of Demo Plan)	Exercise results	Demonstration objective status (OK, NOK, POK (Partially OK))
	CRT-POD-002-004	• The system did not notify the supervisor when new submissions were added from pilots Supervisors recommend to provide notifications in the event of new requests. • It was possible to grant permission for flights that could potentially lead to conflicts. Supervisors recommend to provide a means of strategic deconfliction.	
		Flight-execution • From the supervisor perspective, the view included in the UTM system enables drone monitoring during flights. • The trackers performed intermittently (accuracy and availability issues); hence ATC and supervisor were not aware of the drone's position at all times. • Supervisor end of the system functioned well. Supervisor was warned about position of drones and whether they were about to collide. • The tablet and mobile version of the system provided only limited information to drone pilots. Furthermore, it was not integrated into the drone software, which thus required an observer to operate the mobile end of the system.	POK
OBJ-VLD-POD-003 Safety	CRT-POD-003-001 CRT-POD-003-002 CRT-POD-003-003 CRT-POD-003-004	Pre-flight: • The pilots were aware of restricted areas and no-fly zones and could also see temporary no-fly zones. • The pilots were aware of restricted area and/or no fly zone • The supervisor was aware of mission but not able to assess fly zone overlaps (e.g. for strategic deconfliction)	POK
		Flight execution: • The supervisor/ATCO gained situational awareness about drone traffic in the area of responsibility. • The dedicated ATCO/pilot interface at Rodez greatly improved situation awareness especially on	POK

Demonstration Objective (as in section 3 of Demo Plan)	Demonstration Success criteria (as in section 5 of Demo Plan)	Exercise results	Demonstration objective status (OK, NOK, POK (Partially OK))
		controllers side • The crew did not receive all safety related information, and was not informed about other drone operations in the vicinity. Situation awareness has to be addressed from the pilot side: knowing who is flying around in order to take proper decision. • It is of concern that the UTM system is a separate system, as a sole pilot will not be able to operate both drone and UTM system. Integration is needed if it should be used for more than a reporting app.	
OBJ-VLD-POD-004 Security	CRT-POD-004-001 CRT-POD-004-002	• All UTM user accounts are protected behind a log-on image and cannot be accessed without credentials and password. • A Dedicated Orange Access Network supported by Firewalls meant that data was transmitted on a secure and dedicated line. • The participants globally reported a neutral impact of the UTM on security compared to today's situation. • As operations under U-Space are highly dependent on automation and interconnected systems, it is highly recommended to define and implement security requirements from the beginning throughout the whole spectrum of U-Space services.	POK
OBJ-VLD-POD-005 Standards and regulation	CRT-POD-005-001 CRT-POD-005-002	Pre-flight: • The format for submitting an ICAO flight plan for the purpose of a drone flight by internet is not clear and does not matches the operational flight plan as currently defined by the U-space service provider. • Regulation for UTM needs to be deployed to ensure appropriate and reliable level of services across Europe. • Specific standards have to be set to ensure proper communication level across all UTM stakeholders • Currently there is no regulation for drone/manned aircraft interaction.	NOK

Demonstration Objective (as in section 3 of Demo Plan)	Demonstration Success criteria (as in section 5 of Demo Plan)	Exercise results	Demonstration objective status (OK, NOK, POK (Partially OK))
		Flight execution: • Regulations currently do not allow small drones to be equipped by light-weight low-power transponders (as these, by design, do not comply with all certification standards, i.e. minimum output power), and there are no minimum standards for these light-weight low-power transponders. • There is currently no rule-based scheme to determine the level of priority of a mission applicable to all U-space systems. • There are no standardised messages between supervisor and drone pilot, e.g. you cannot send a "land now" to the pilot or "give way". Today, all communication while in flight has to be done via radio.	NOK
OBJ-VLD-POD-006 initial benefits assessment	CRT-POD-006-001 CRT-POD-006-002	Pre-flight: • For flight preparation, the participants expect strong gains in terms of mission effectiveness and cost reduction through improved mission preparation (quicker/easier planning for operators due to easy approvals).	OK
		Flight execution: • During flight execution, all actors involved (drone pilots, ATCO, supervisor and authorities) see benefits from real-time awareness of drones location and mission context (e.g. restricted areas, other traffic). • Based on the experiences at Marknesse, for more complex scenarios, the supervisor role would benefit from more (or completely made redundant) automation, especially outside of manned controlled aerodrome environments. • Flight crew advise that situational awareness during flight execution is key to gaining flight efficiency and safety benefits. Moreover, the extent to which the UTM and drone flight controls are integrated will impact workload and therefore costs and benefits.	POK

Table 10 - Summary results based on flight phases

4.2 Detailed analysis of Study Results per objective

4.2.1 OBJ-VLD-POD-001 Operational feasibility and acceptability results

The aim of this objective is to demonstrate the impact on human performance (HP) through the assessment of the operational feasibility and acceptability of the addressed U-space services. The findings encompass the results obtained in all five sites for the pre-flight services and flight execution services, through questionnaire data, debrief discussions and expert observations. Additionally, other HP aspects that were assessed or that emerged out of the demonstrations will be discussed in this chapter. For a complete list of Human Performance related requirements and recommendations, please consult Appendix B.

The graphs included in this section have been separated for the mission execution phase between the supervisor and the flight crew to ensure an appropriate interpretation of the results. For the mission execution phase, the supervisor ATCO in Rodez has been analysed separately, as the collaborative interface used was different from the Unifly tool.

Overall, the results should be interpreted with caution. Based on the textual comments from the questionnaires as well as through expert observations, it has been concluded that it was difficult for the participants to separate the Unifly system used in the demonstrations from the U-space concept. Hence, especially the "low" and "very low" ratings from the upcoming graphs are mostly attributable to the fact that the participants lacked some functionalities/information in the system rather than rejected the concept as a whole. Additionally the limited familiarity of the participants with the tool might have influenced the results.

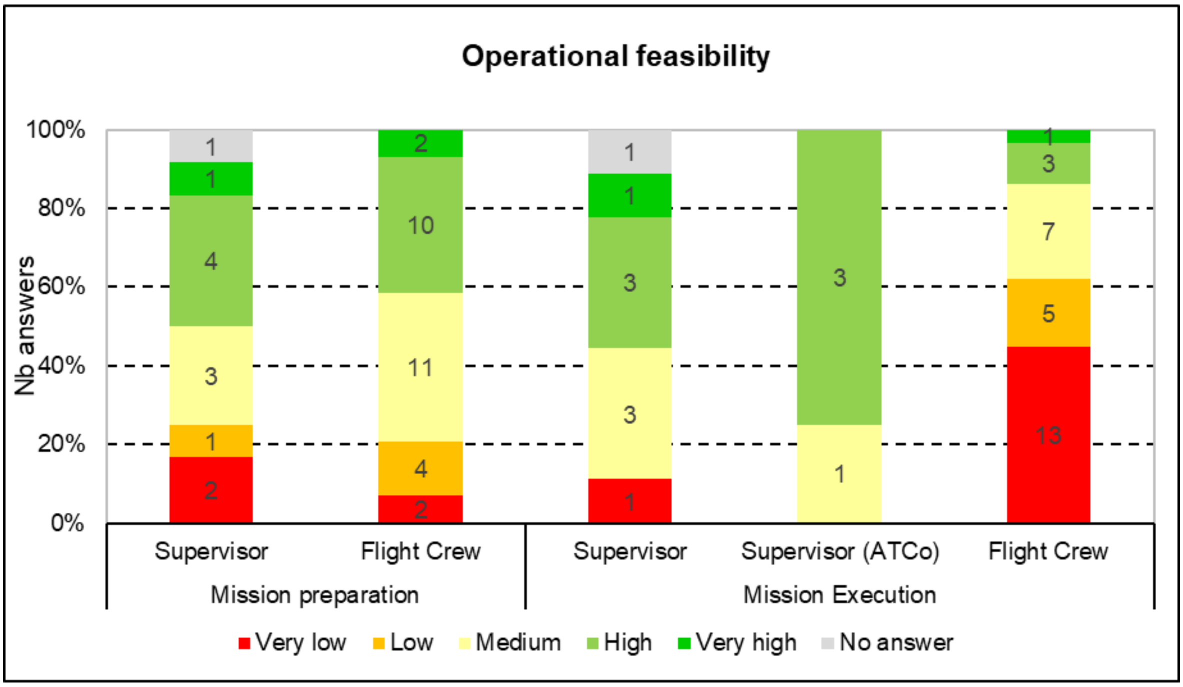


Figure 8 - Operational feasibility/acceptability of the UTM system

For the mission preparation phase, the results indicate that in majority both the flight crew and the supervisors found the system to have a "medium" to "high" feasibility/ acceptability level. The supervisors confirm the usefulness/ effectiveness of having an overview on the missions and the corresponding details (e.g. drone identification, pilot identification etc.) while the flight crew found the flight plan submission concept of operation clear and acceptable.

For the mission execution phase it has to be noted that the "very low" ratings are accounted by the fact that only the supervisors had access to UTM system. Due to the unavailability of a flight view application during the early flights, the flight crew was unable to see all needed information during the flight execution phase. The supervisors gave an overall positive feedback with regard to the feasibility of the UTM system, although concluding that the Unifly interface alone did not suffice as sole means for conflict detection/alerting.

Overall, the participants agree that with an enhanced UTM system encompassing all relevant data displayed into one interface, they will have access to a more effective authorisation process. This facilitates more accurate information during the flight (i.e. flight crew device), and enhances their situational awareness. From the supervisor`s perspective an efficient authorisation process would encompass an "automatic flight permission feature". Whereby the supervisor would only intervene in case of emergency or re-planning. Additionally, the supervisors anticipate that an enhanced UTM system would help ensure "de-conflicting drone operations", although a rule-based and automated supervisor function should be embedded in the UTM system, in order to avoid the "human" supervisor to answer to "unexpected" scenarios with multiple flights.

Apart from the technical enhancements elaborated in paragraph, phraseology and coordination procedures shall be defined between all actors involved (pilots, supervisors and ATCOs), in order to ensure the smooth operability.

The ATC collaborative interface tested in Rodez was found to be globally operable and acceptable by the air traffic controller supervising the drone operation.

Furthermore, based on their experience, the flight crew and the supervisors anticipate a relatively easy and comfortable transition from the current operations.

4.2.1.1 Roles and Responsibilities

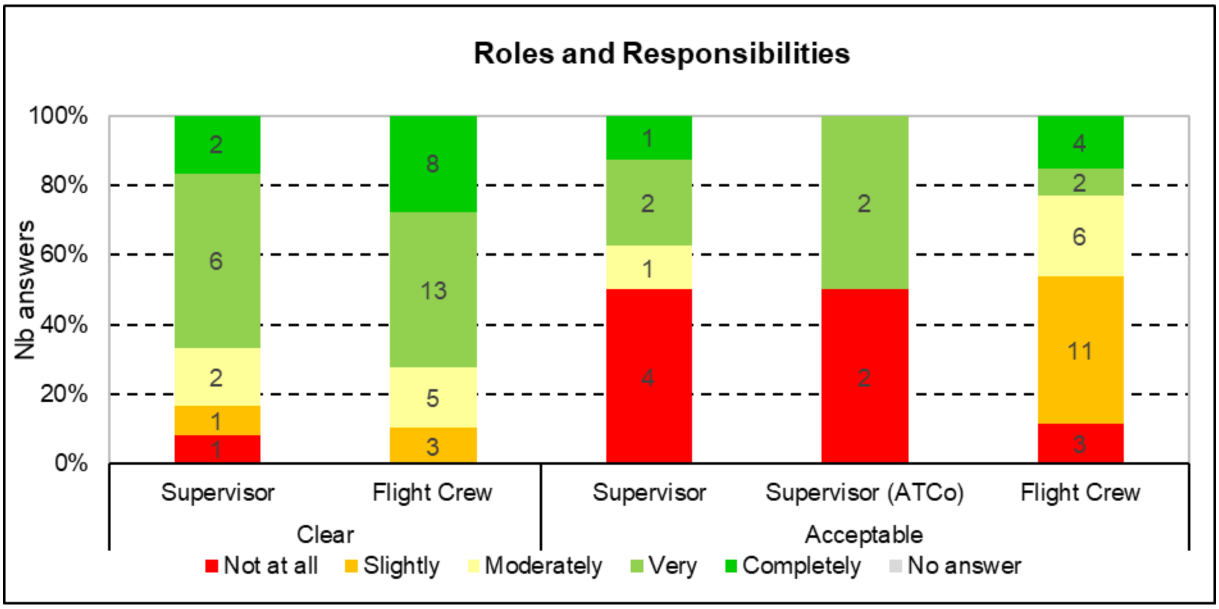


Figure 9 - Roles and responsibilities

As shown at Figure 9, the majority of the participants replied positively (i.e. "very" or "completely") when asked how clear were the roles and responsibilities and their associated tasks and procedures in the demonstrations.

On the other hand, the results indicate that the roles and responsibilities were less acceptable with the majority of answers indicating a "slightly" acceptable rating or "not at all acceptable". The results can be attributed to the fact that the flight crew and drone supervisors were not fully trained and familiar with the new responsibilities and associated tasks, relying on their previous experience in the drone industry, which might have influenced their performance and perception. Moreover, the fact that the flight crew was not able to see the flight view in the flight execution phase, made their responsibilities rather limited as they were not able to see their drone, the other operating drones or the "no fly" zones.

4.2.1.2 Usability of the UTM system

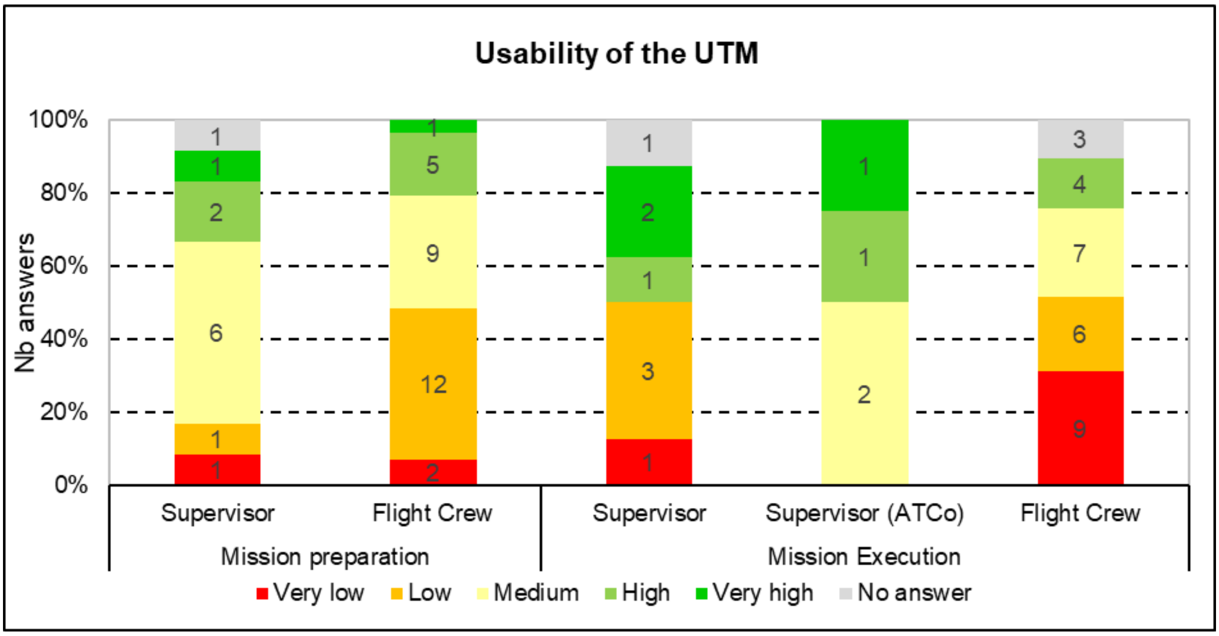


Figure 10 Usability of the UTM system

The usability of the UTM system graph indicates a wide array of opinions from the participants, with a majority of "medium" and "low" ratings for the mission preparation phase and with fairly similar percentages of answers for "medium", "low" and "very low" levels for the mission execution phase.

As aforementioned, the participants had difficulties separating the UTM system prototype used in the demonstration and the UTM concept as a future technological improvement. Based on observations and textual comments from the questionnaires, we can conclude that the negative ratings given for usability are addressing the prototype that requires additional refinements. The fact that the user interface required "too many clicks and inputs", had slow loading times and lacked some functionalities have been some of the reasons behind the low ratings given by the flight crew and supervisors.

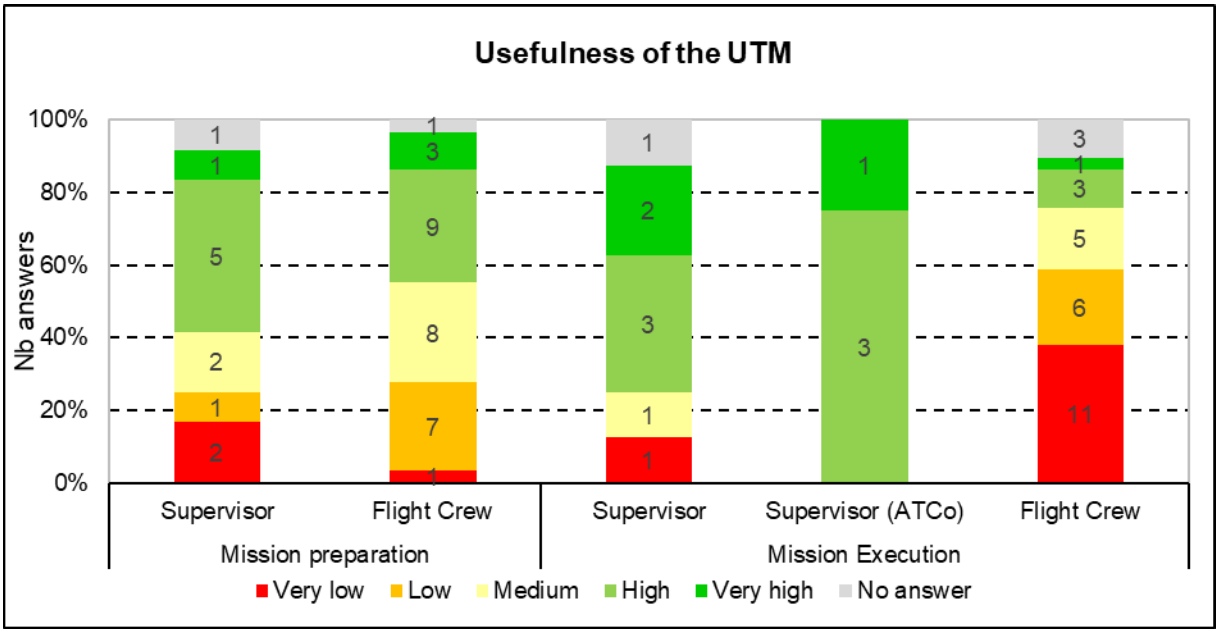


Figure 11 - Usefulness of the UTM system

The mission preparation phase indicates that in majority the participants have found the system to have a “high” usefulness, although particularly in the flight crew results we find quite high rates of answers corresponding to a “medium” or “low” usefulness. The results are in line with the usability scores that indicate that due to the prototype limitations, the actors involved in the demonstrations did not experience the full benefits of the system.

For the mission execution phase, the majority of unsatisfactory answers is attributed once again to the fact that the flight view was not available at this stage to the flight crew.

Overall the conclusion of the participants was that the UTM system represents a good basic idea that that needs to be improved, specifically from a technical perspective.

4.2.1.3 Situational Awareness

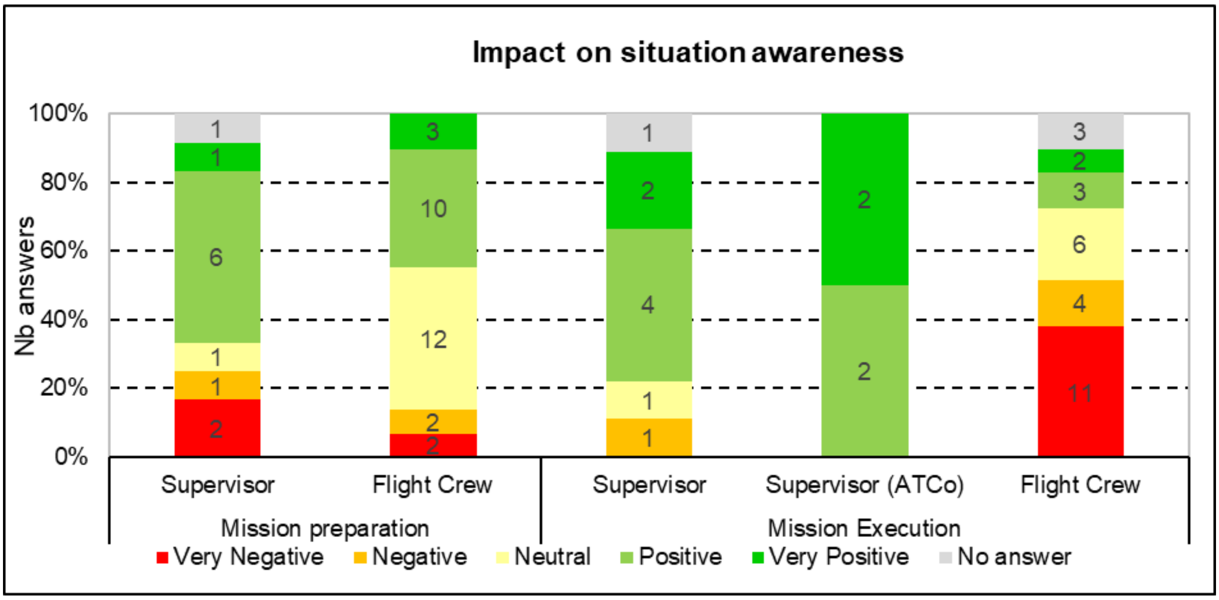


Figure 12 - Situational awareness

For the mission preparation phase, the impact of the UTM system on situation awareness was in majority "positive" for the supervisors, and "neutral" and "positive" for the flight crew. Because the flight crew had no oversight of the other drone operations in the vicinity and as a result did not know which airspace was available for their flight their situational awareness was not fully enhanced by the addition of the UTM system. After each flight, the crews grew more familiar with the system, and consequently gave more scores that are positive. This explains the spread in scores (from negative to positive) because the diagrams combine the evaluations of all flights, and hence contain the negative scores from the initial flights as well as the more positive scores from the later flights.

Because the flight crew had no UTM interface available during the flight execution phase and hence they were not able to monitor their own flight, the impact of the UTM system is seen as less positive for mission execution. Contrary to the flight crews, the supervisors did have an overview of all flights; therefore, their scores are more positive.

Overall, the participants agree that with an enhanced UTM system, situation awareness will be positively impacted in both the preparation phase and the execution phase.

4.2.1.4 Trust

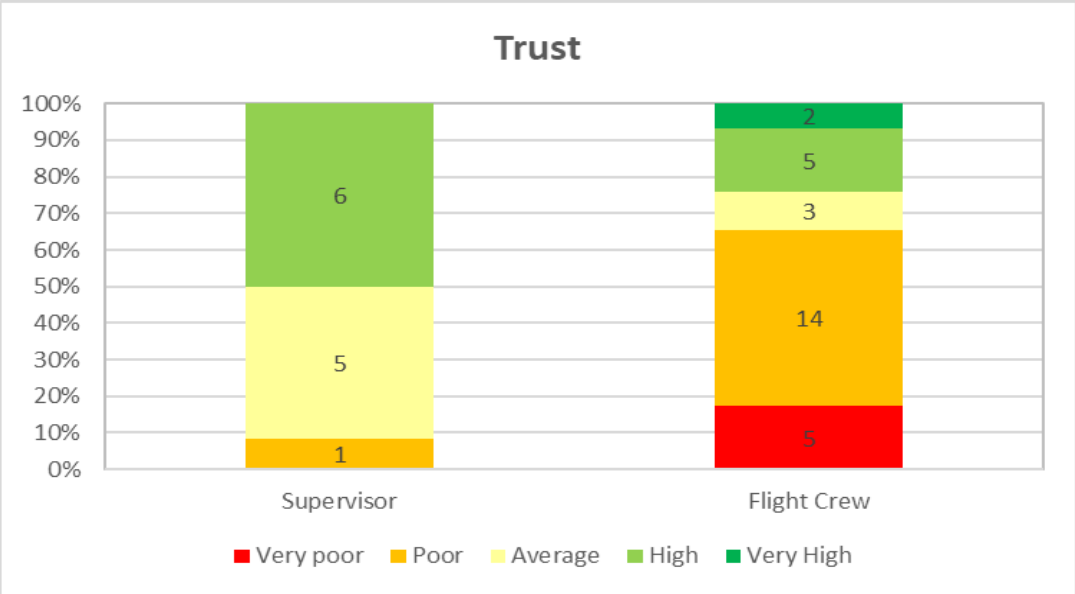


Figure 13 - Trust

In line with the other aspects discussed in chapter 4.2.2, the trust results are influenced by the fact that a prototype was used during the demonstrations. The need of further refinements to the current UTM system was communicated. One of the main benefits of PODIUM are the technical improvements envisaged by the participants.

4.2.2 OBJ-VLD-POD-002 Technical feasibility

The aim of this objective was to assess the technical feasibility of the various systems (e.g. trackers, Unifly U-space system). In addition to participants' comments and feedback during debriefing, this assessment was done using questionnaires items (assess Timeliness and Accuracy of information provided by the technical systems) and some objective logs (e.g. communication latency between tracker and U-space systems and 3D drone position from trackers).

It should be reminded that as stated at paragraph 3.1, different trackers using various technologies were used in the various sites. Therefore, results could differ from one site to another.

4.2.2.1 Flight preparation services/capabilities

During flight preparation phase, the technical system only consisted in the UTM system used to prepare, submit and provide authorisation for the mission.

UTM system

As illustrated in Figure 14, the timeliness and accuracy of information were rated in overall medium by the supervisor and slightly better by the pilots during flight preparation phase (~40% of pilots rated high or very high).

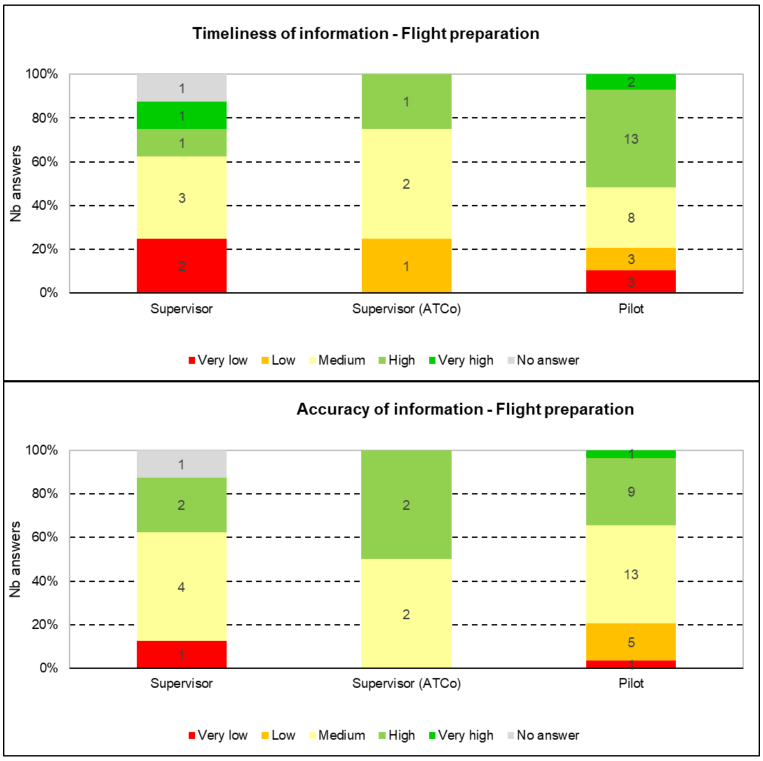


Figure 14 - Ratings on timeliness (top) and accuracy (bottom) of information- Flight preparation

From the supervisor perspective, the system enables to access mission and pilots' forms and allow exchanges with the pilots through specific tabs in the software. However, in addition to usability issues, some crucial features are missing in the tested system. It is recommended to provide notifications in case of new mission request, and to provide means of strategic deconfliction. Indeed, in the current state it is not possible for the supervisor to assess whether several requested missions are overlapping in terms of lateral, vertical area and/or time schedule. These additional features would improve decision making to accept the mission and enable efficient flight area management.

The pilots appreciated that the system automatically "validate" the mission according to current regulation, with some information available for missions planning (e.g. restricted area, no fly zone). However, some information are missing (e.g. NOTAM[1] and wind turbine). It is therefore recommended to add such information to improve mission preparation. In addition, to increase interoperability between the UTM system and other pilots tools to plan missions, they would appreciate to be able to import KML files[2] in the system to prepare their mission.

[1] In fact, no relevant data was provided to load it into the system. For the NOTAMs, no specific parsing rules have been discussed to determine which NOTAMs are applicable for drones?

[2] KML stand for Key Mark-up Language. It enables defining geographical places, volumes, path… and is now commonly used for geospatial data definition and exchanges.

4.2.2.2 Flight execution services/capabilities

During flight execution phase, the technical systems consisted in the UTM system for the supervisor to monitor the mission and the trackers providing drone 3D positions. In addition, a prototype of mobile application was provided to pilots.

It should be emphasised, that during Rodez demo, a dedicated collaborative interface was developed to support monitoring of the drone mission by the Air traffic controllers (supervisor role here) during flight execution. Therefore, the results are presented separately for supervisor and Rodez ATCO with a specific focus on the collaborative interface (see below).

UTM system

As illustrated in Figure 15, the timeliness and accuracy of information were rated medium or high by most of the supervisor whereas low or very low for half of the pilots in overall during flight preparation phase.

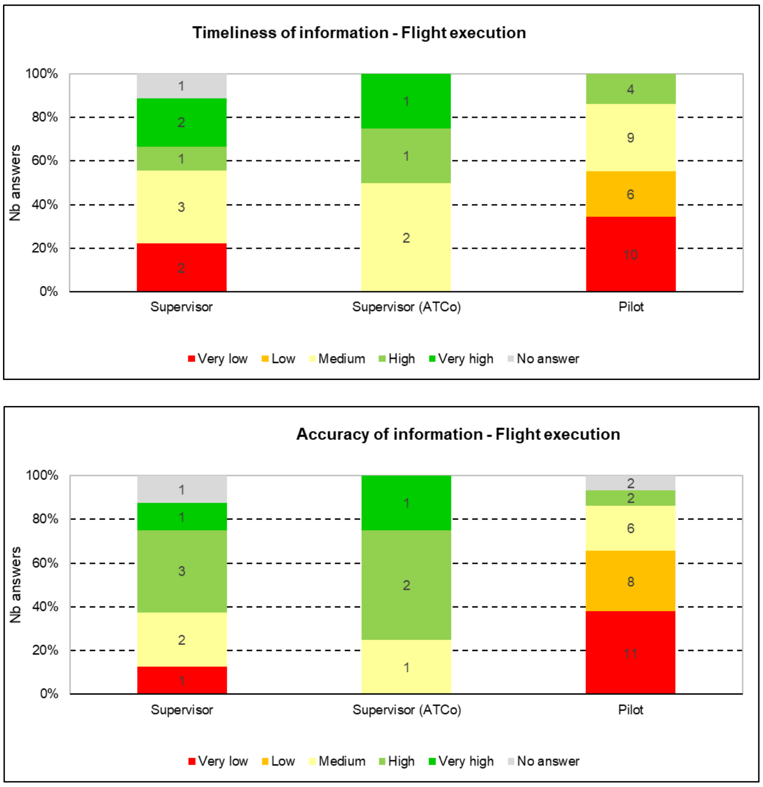


Figure 15 - Ratings on timeliness (top) and accuracy (bottom) of information- Flight execution

From the supervisor perspective, the view included in the UTM system enables drone monitoring during flights. Planned mission, tracks (past positions) and separation between drones are also available. However, it assumes that all the flying object (other drone and/or other manned aircraft e.g. GA aircraft) must be “visible” in the UTM system. This was not always the case depending on the tracker technology used or in case of non-transponder equipped aircraft.

In addition, some features are missing to further support supervisor tasks. Indeed, in the current state of the system, the supervisor is not warned when the mission starts and if the drone flies outside the defined/planned area. Therefore, it is required to provide such notifications.

Figure 16: Unifly supervisor view showing HIONOS tracker during Bretigny demo.

From the pilots' perspective, the mobile application prototype provided during the demo did not bring much information, as only including take-off and landing button. To support pilots during flights, it is required to make piloting software (from different manufacturers) and the UTM system interoperable.

<u>Collaborative interface (Rodez specific)</u>

As illustrated in Figure 15, the timeliness and accuracy of information provided by the collaborative interface was globally found high by the ATCO supervising the flight. The system was stable over time and the delay of communication was compatible with the requirements.

As mentioned in operability section, the collaborative interface provided accurate information on drone positions in line and integrating other features of the supervisor (ATCO here) radar view. This technical system also enabled silent communication through messages with the drone pilots during flights (e.g. for CTR entry clearances).

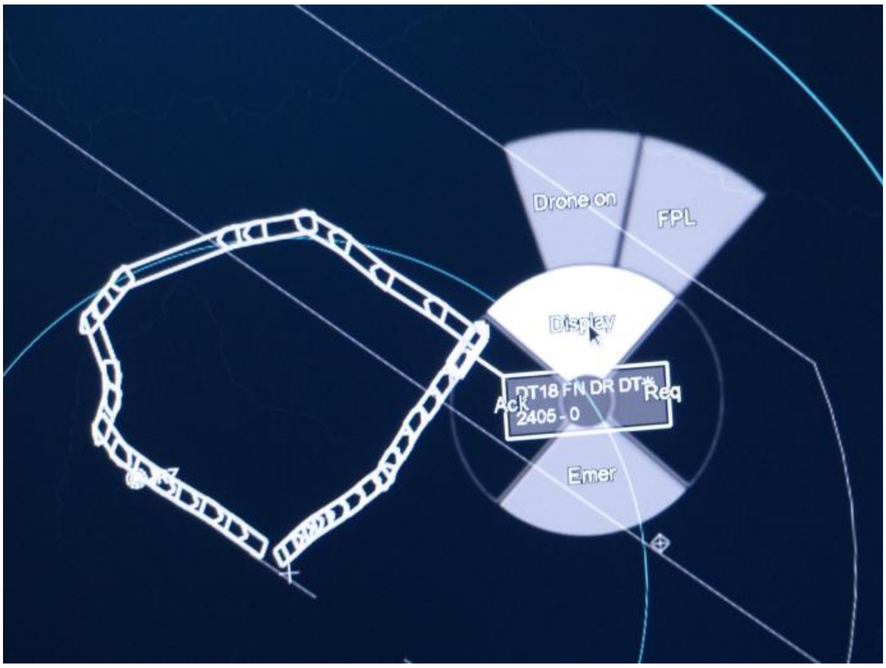


Figure 17: ATCO collaborative interface (Mission plan and Pie menu)

On pilots' side, the communication with the Air traffic controller was ensured by an Airbus mock-up software displaying messages received and enabling to send request (Figure 18). For the demo purpose, this software was not integrated in the piloting software used by the pilots. According to them, it is required to integrate them to enable pilot exchanging with the controllers while monitoring flight parameters in the piloting software.

Figure 18: Mock-up of collaborative interface for drone pilots

Trackers and communication systems

Various trackers and communications systems were used on the demo sites and the performances and accuracy of those systems appeared as key aspects to support the U-space services.

The demonstrations showed significant differences between the drone positions when measured on different trackers. Discrepancies were measured in terms of lateral positions (see Figure 19) and vertical positions (Figure 20). In this last case this might be explained by different reference altitude used (QNE vs. QNH). This led to uncertainty whether the drone is on ground or not and so may degrade operations efficiency. In addition, some glitches involving positioning errors or loss of the position appeared sometimes for the trackers.

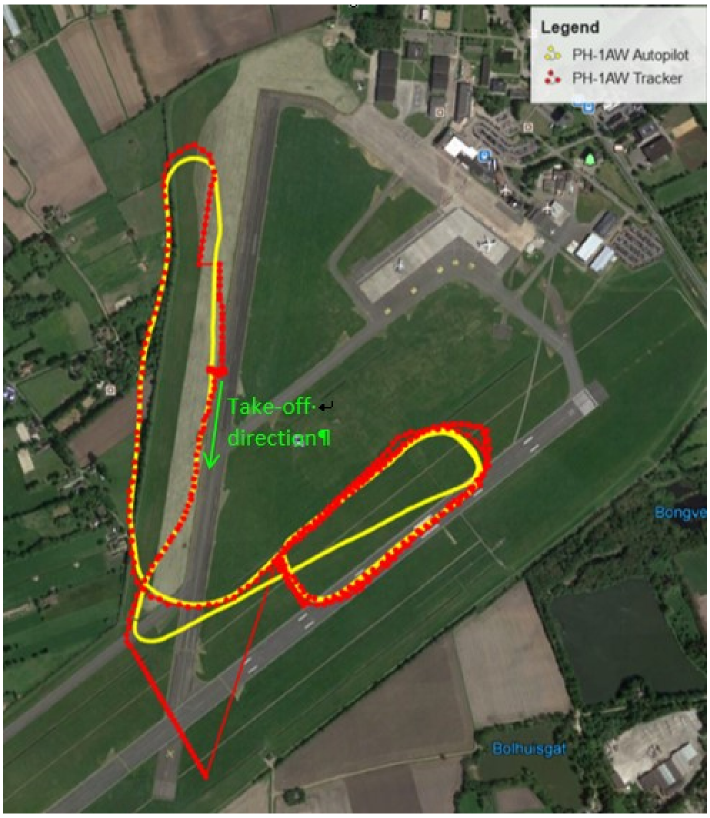


Figure 19: Comparison of PH-1AW GPS position from autopilot (yellow) and tracker (red).

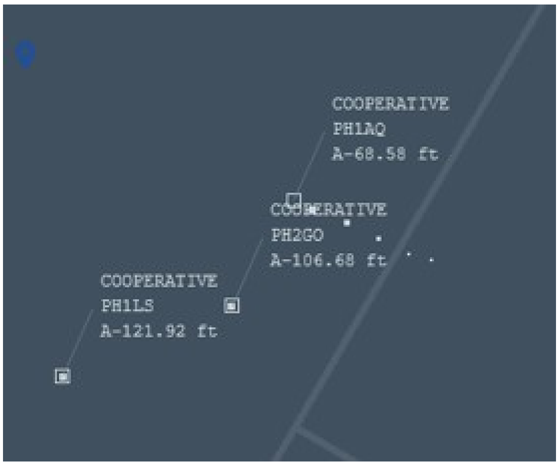


Figure 20: Different height readings for drones on the ground

As a result, standardisation and regulation of trackers (e.g. in terms of accuracy, altitude and robustness) and communication system (e.g. latency of communication) are required to ensure safe and efficient deployment of U-space services.

4.2.3 OBJ-VLD-POD-003 Safety

The validation objective related to safety is focused in the maturity of the U-space services in terms of safety rather than the safety means putted in place during the performance of the trials to maintain the required safety level when conducting the demonstrations. This means that the safety objective demonstrates the contribution of the U-space services to drone operations in the following way:

- How UTM systems increases safety levels by provision of appropriate data from pre-flight to post-flight phases.
- Showing the contribution of the U-space services to limit air risks in VLL airspace.
- Showing the contribution of U-space services to limit ground risks.
- Demonstrating the capability of U-space services to decrease the risk of penetrating no-fly zones.

This increase in the safety level produced by the U-space services has been shown through the usage of the UTM platform by the participants and their feedback provided before, during and after the operations. As a result, the air-risk has been effectively mitigated by the implementation of the tracking systems and the HMI interfaces allowing segregation with manned traffic. The pre-flight tools utilized allowed to mitigate the air-risk by proportioning strategic de-confliction and situational awareness of possible conflicts routes of surrounding traffic. During the execution of the drone flights the services deployed allowed to perform conformance monitoring with the involved traffic which allowed to reduce sensibly the risk of collision in the air.

The ground risk has been effectively mitigated as well. On one hand in the pre-flight phase by the mission preparation supported by the UTM platform minimizing this risk by avoiding populated areas and critical infrastructures. On the other hand, during the flight execution phase the usage of the tracking system and HMI interfaces permitted to monitor and avoid in case of necessary possible unforeseen conflicts/obstacles. Post-flight data captured during flights appropriately processed could additionally contribute to mitigate ground risk for posterior flights in the respective flight volumes/areas.

Moreover, no fly zone infringements has occurred neither situations that could induce a breach into a no fly zone or proximities to those due to the appropriate situational awareness of pilots, controllers and supervisors provided by the system in relation to these areas.

In general, the system contributes to augment the situational awareness of all participants involved in the demonstrations at different levels; in particular, increasing the possibilities for conflict detection/alerting and flight mission update during the flight services execution. This is seen as a positive step for the U-space services deployment to ensure and progressively increase safety in todays and future operations.

Nevertheless, certain drawbacks have been observed in the system to its contribution to the safety of the operation. These weaknesses detected come from the following issues:

- The situational awareness is not uniform among all actor being the drone pilots the most limited ones in this aspect. They reported certain lack of awareness to avoid obstacles and/or other airspace user as could be general aviation users.

- The tracking systems have still a considerable number of limitations that need to be overcome to permit routine operations in non-segregated airspace. For instance, the altitude provided by the tracker needs to be provided in an accurate and reliable manner. Improvement in the internal algorithms supporting the tracking and additional tools for conflict detection and alerting based on further experience are needed. Inclusion of the general aviation in the “air picture” to facilitate the effective separation of all airspace users.

- There is a lack of common reference altitude for UAS, which contributes to the lack of a standard altitude in the tracking systems and the appropriate standard phraseology during communications.

- Absence of standardization for flight rules and contingency measures as fall-back procedures or loss of communications.

- There are no rules concerning separation both horizontally and vertically. Separation rules must be defined for both UAV vs UAV and UAV vs crewed aircraft. Higher efforts in this field have to be taken for the implementation of effective separation procedures and tools allowing automatic conflict detection and conflict resolution.

- Limitations observed with regards of conflict detection rules/algorithm.

- Lack of standards related with the available information used and provided during mission preparation and flight approval. Furthermore, the data utilized in the UTM system is desirable to be based in precise data coming from reliable sources in the best of the cases having being verified by a certification process.

- Limitations of the system to allow a risk based approach (i.e. level of performance commensurate to the level of risk). It is considered convenient the possibility to offer different levels of performance of the system depending on the risk level of the mission. This would involve different the accuracy level of the tracking, level of communication, variable level of service provision to different airspace users, etc.

- Other technical requirements related with the accuracy of the system.

The aforementioned limitations are expected to be overcome in some measure after further industrial development steps that will allow producing and analysing bigger amounts of reliable data. These data will permit precise quantification to populate safety models, appropriately designed for U-space operations, granting that way the complete maturity of the U-space services at all levels. Further analysis of these limitations is provided in Appendix C (Safety assessment report) with recommendations and requirements to be put in place to facilitate future deployment.

4.2.3.1 Perception of safety with support of U-space services

The survey distributed among the participants during the demos has identified a positive impact to the operations' safety of the UTM system. This is illustrated by Figure 21 where five out of eight supervisors confirmed a positive repercussion on safety while the other three remained as neutral the influence of the system. Moreover, ATCOs and supervisors identified unanimously the positive the impact of the system with regards of the safety impact to the operations being the feedback of one of them very positive (Highest degree in the scale). On the other hand, the opinions between the pilots where widely distributed, among twenty-nine participants eight opinions were observed as a negative impact of the system in the safety while twelve informed of a positive or very positive impact, finally nine of them reported a neutral effect on the safety. The reason of this diversity in the opinions can be explained due to the usability of the system rather than the information provided by it. This would state the need of a better integration or usability of the system for the usage of the pilots when performing flights.

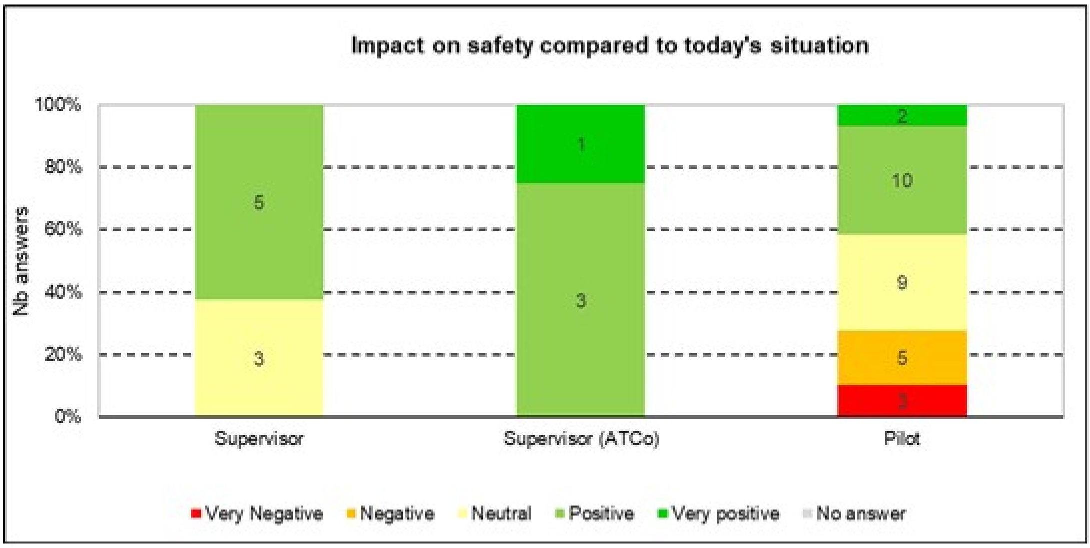


Figure 21: Ratings on UTM impact on safety

As a summary of the results obtained in the questionnaires, it can be said that the majority of the users reported that the UTM system could potentially improve the current level of safety. An increase of the situation awareness is foreseen by pilots and supervisors through the availability of current "air situation" shared among all the parties.

4.2.4 OBJ-VLD-POD-004 Security

Due to the nature of PODIUM the project (consisted in flight trials), the security aspects was lightly addressed. Considering that the objective was to investigate the suitability of current and proposed U-Space solutions, the focus of the security section will be on the cyber security, i.e. security issues caused by attacks on the drone infrastructure with the aim of disrupting the orderly execution of drone operations second area.

The following results are based on feedback from participants and a generic security assessment (See Appendix D).

As illustrated in Figure 22, the participants globally reported a neutral impact of the UTM on security compared to today's situation. However, as operations under U-Space are highly dependent on automation and interconnected systems, it is highly recommended to define and implement security requirements from the beginning throughout the whole spectrum of U-Space services. As a result, formal security case should be conducted as part of the U-space concept of operation. This could be done through identification of security objectives and requirements of all U-space assets (e.g. UTM system, communication/navigation infrastructures) based on a success approach (absence of failure within the end-to-end system) and a conventional failure approach.

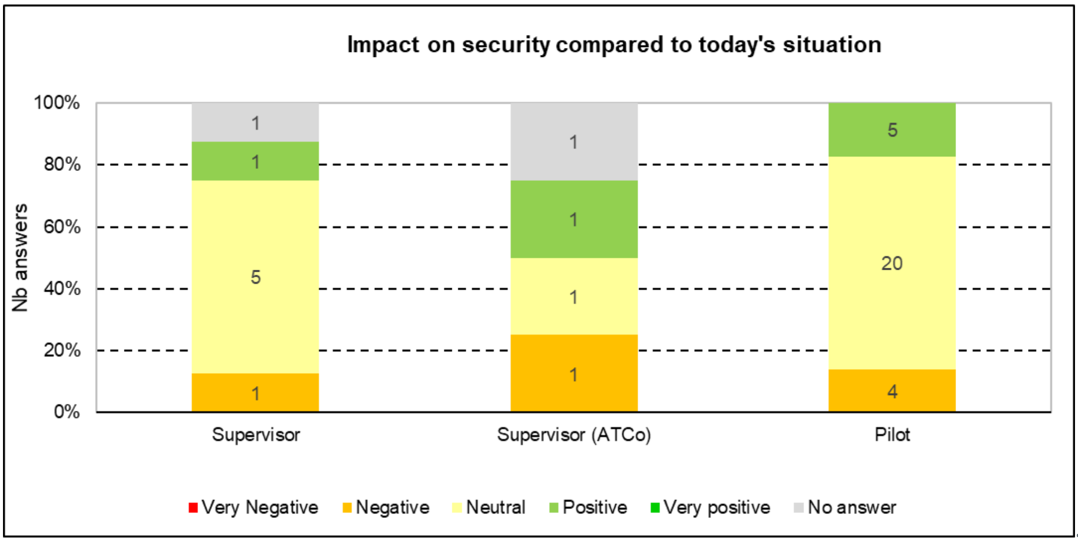


Figure 22. Ratings on UTM impact on security.

4.2.5 OBJ-VLD-POD-005 Standards and regulation

The aim of this objective was to assess the impact of the of U-space services on standard and regulation. This assessment was done using questionnaires items and feedback from the participants. The project could benefit from the fact that the trials were conducted over three different countries (implying different regulation) and various systems (tracker, communication means) that may require different standards.

Globally, these aspects raised several questions/concerns regarding responsibility, liability, data privacy and reliability, systems standards and certification (trackers, communication, UTM systems) and cost of the U-space services in a growing drone business market

4.2.5.1 Flight preparation services/capabilities

One of the main issue mentioned by the participants was the lack of common European regulation and standard (framework) to submit and request flight authorisation according to the scenario to be performed (e.g. VLOS/BVLOS, rural/urban). For example, the trials showed different regulations in Netherland and in France to request flight authorisation within a CTR and no defined/standardised fall back, priority procedures or messages between operators and supervisor.

Although a common UTM system is foreseen and expected to be an efficient tool to support European regulation and standard, the participants also raised questions on data certification (e.g. who is responsible for defining restricted areas or no fly zones, are data reliable, who will be liable in case of problems) and data privacy/security in a competitive market.

4.2.5.2 Flight execution services/capabilities

When in flight, the main concerns expressed by the participants was in terms of reliability and standardisation of the various technical systems used especially in the context of increasing drone activities. Indeed, a key aspect to conduct safe and efficient operations is the fact that all airspace users should be "visible" through the UTM systems. Therefore, it impacts standards and regulation in terms of infrastructures, communications systems performance (e.g. trackers/transponder performances, technology, network coverage) and interoperability across the various system technologies.

4.2.6 OBJ-VLD-POD-006 initial benefits assessment

Initial benefits of the U-space services used during the demonstrations were assessed notably in terms of cost effectiveness (e.g. time, effort and costs), safety and capacity (e.g. potential for more simultaneous flights). As a demonstrator project, PODIUM did not aim to measure and quantify cost effectiveness and capacity increase, but could only base these on the expert judgment of the participants (drone pilots/operators, supervisors and air-traffic controllers).

Feedback from drone pilots and supervisors are mixed. Although participants clearly identify potential benefits of U-space services, their assessment was impacted by the limitations of the UTM system tested. For mission preparation, the participants expressed potential gain in terms of mission effectiveness and cost reduction through improved mission preparation (quicker/easier planning for operators due to easy approvals). During flight execution, all actors involved (drone pilots, ATCO, supervisor and authorities) see benefits from real-time awareness of drones location and mission context (e.g. restricted areas, other traffic).

From the Air Traffic Controllers (supervisor ATCO), the ATC collaborative interface was clearly assessed as beneficial, as it provided controllers with a real-time awareness of the drone traffic situation and enabled an improved communication with drone pilots/operators (Figure 23)

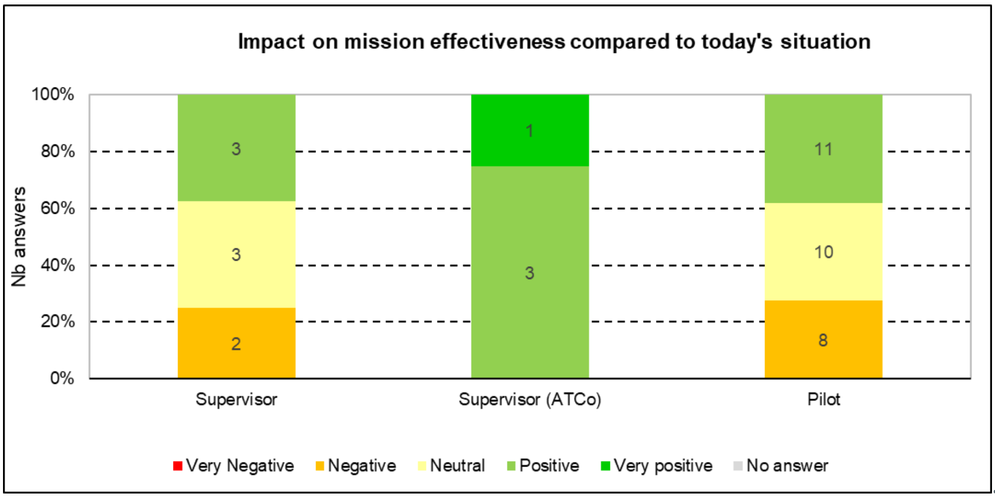


Figure 23. Ratings on UTM impact on mission effectiveness.

In addition to assessing the impact on mission effectiveness (as reported on Figure 23), the participants identified the main potential benefits of U-space services, essentially in terms of safety and capacity:

- Improved safety of the airspace (decreased Air to Air risk) due to better situational awareness during mission preparation and mission execution. In addition they can see better interaction with other airspace users through the UTM monitoring and communication services based on agreed regulation.
- Increased capacity due to extended mission possibilities (more simultaneous BVLOS opportunities) and better situation awareness.

4.3 Confidence in Study Results

4.3.1 Limitations of Study Results

The limitation came from the various unexpected events previously described in section 3.3.

Operational

The main operational limitation relates to the nature of the exercise which consisted in flight trials demonstration lasting several days over the various sites. First, bad weather led to postpone and reduce the number of flight initially planned. Second, a few scenario had to be adapted for regulatory and safety reasons (e.g. automated flight instead of autonomous, reserved area for drone demonstration without any other traffic around when in CTR). Therefore, this led to some limitations in terms of realistic operational scenarios.

Technical
During a few flights, some technical problems occurred with the tracker leading to a loss of signal in the supervisor view.
The UTM software prototype also experienced technical problems and lacked some features that were not available in time for the demonstration or not implemented features.

Participants
During the demo, the pilots/operators were well briefed on the scenario and procedures to fly and so the assessments by the flight crews may not be totally representative for less experienced pilots/operators.

On the other hand, a lack of familiarity with the UTMs system used during the demo (1 hour of guided training) might have influenced the supervisors' performances.

Data collection
Most of the qualitative assessment made on U-space services was conducted through questionnaires. Although it was emphasized to focus on the U-Space services and principles, as a concept and not on the specific UTM system available for the demonstration it was difficult for the participants to distinguish between the U-space services and the specific system that they were using. This is reflected in some of the interim conclusions. Nonetheless, the feedback provides insight on which aspects to improve and recommendations for next steps.

Limitations experienced on each individual site are detailed in the appendices.

4.3.2 Quality of Study Results

Despite the limitations mentioned above, the quality of the results is considered as high essentially due to the nature of the exercise. Indeed, it consisted in flight trials performed in a real environment (Rodez CTR, Groningen/Markenesse airport, DPR/Odense reserved area) by professional pilots/operators from various drone business companies and under the supervision of flight area current supervisor. The variety of the panel of participants (pilot, operator, flight area supervisor, air traffic controller, drone manufacturer, specific drone solution providers,) also contributes to the high quality of feedback/results.

U-space services were mainly addressed qualitatively through consistent questionnaires and debriefing conducted on each individual site. The main results from the PODIUM trials were presented and debated with a wider range of stakeholders during visitors day organised on each site. The feedback from the stakeholders present was in line with the project teams findings. The quality of results obtained on each individual site are detailed in the appendices.

4.3.3 Significance of Study Results

As stated above, the flight trials were conducted in realistic and varied environments and included BVLOS performed by professionals. Participants from a wide range of experiences/activities in drone business submitted 41 post demo questionnaires providing significant feedback and recommendations for next steps. The results, however, mainly rely on feedback from participants (qualitative) and so no quantitative statistical analysis (with significance test) could be performed.

Significance of results obtained on each individual site are detailed in the appendices.

5 Conclusions and recommendations

The main objectives of PODIUM have been to demonstrate current state-of-the-art U-space/UTM concepts and systems in operational environments; to assess their maturity; and to make recommendations regarding their deployment.

The project has performed 18 operational scenarios for VLOS and BVLOS flights, involving 73 actual flights and 138 flight authorisations, at Hans Christian Andersen Airport, Odense; the Drones Paris Region cluster, Brétigny; Rodez-Aveyron airport; the Netherlands RPAS Test Centre, Marknesse; and Groningen Airport Eelde. Further to familiarisation flights and mock-ups in late 2018 and early 2019, the bulk of the flights were performed in the period May to June 2019. Five visitors dates attended by local stakeholders were held at each of the sites.

The project has collected validation data from: 41 post demonstration questionnaires completed by participants; 5 facilitated de-briefing sessions; and observations from EUROCONTROL validation experts and partners. It is important to keep in mind that the demonstration results rely mainly on feedback from the participants (qualitative) and that no quantitative statistical analysis (with significant test) has been performed.

This section provides a project-wide view of the main conclusions and recommendations resulting from the PODIUM demonstrations, as agreed by the PODIUM partners. The PODIUM Project Management Team – during its meeting at EUROCONTROL on 18-19 September 2019 – reached a consensus on these conclusions. Moreover, these same conclusions and recommendations were presented to the PODIUM dissemination event held at EUROCONTROL Brussels on 17 October 2019.

Where appropriate, this section makes reference to the SJU ‘Guidance for U-space conclusions and recommendations’ [23].

5.1 Conclusions

The main project-wide conclusions resulting from the PODIUM demonstrations and the analysis of the data collected are now described.

1. Drone operators strongly confirm the need and potential benefits for U-space/UTM solutions that ease the workload and reduce delays for acquiring drone flight authorisations.

2. Drone operators, air traffic controllers and supervisors strongly confirm the need and the potential benefits for U-space/UTM solutions that improve situational awareness and communications, for both the flight preparation and flight execution, to improve operational efficiency and maintain safety.

3. Drone operators require a positive business case to justify the take-up of a U-space/UTM solution. As highlighted by Drones Paris Region: “identify benefits for users and they will pay for it!”

4. Drone operators, air traffic controllers and supervisors confirm the operational and technical acceptability/feasibility of the current PODIUM U-space/UTM solution for the flight preparation phase (corresponding to U1 and some U2 services), albeit with the following remarks:

a. The UTM/U-space system must allow access to trustworthy aeronautical, national and local legislation data applicable to drone operations. For example, this includes the need for approved data for populated areas, bridges, electrical power lines, etc.

b. The user satisfaction with U-space/UTM will be strongly influenced by the usability and accessibility of the HMI;

c. There is a strong preference amongst professional drone operators for a single access point to all of the necessary services, and which is compatible with existing national registration systems (this implies strong interoperability requirements in the context of a competitive open market with multiple service providers).

d. The traceability between the drone registration ID and the tracker ID must be ensured.

5. The air traffic controllers and supervisors confirm the operational and technical acceptability/feasibility of the current PODIUM U-space/UTM solution for the flight execution phase (corresponding to some U2 services), albeit with the following remarks:

   a. As confirmed by the Rodez demonstrations, professional drone pilots and air traffic controllers have a strong preference for an automated messaging system that reduces workload and does not occupy the tower frequency

   b. In the absence of an automated messaging system, clear R/T communications procedures and phraseology between the pilot and the air traffic controller/supervisor are essential.

   c. As confirmed by the Marknesse demonstrations, it is very challenging for a "human" supervisor to respond adequately to "unexpected scenarios" involving multiple drone flights. In such cases, a rule-based and automated supervisor function is essential.

6. The drone operators, air traffic controllers and supervisors confirm the operational and technical acceptability, and potential benefits, of the trackers (ADS-B 1090 MHz, GSM, and L-band UNB) and the access point name/roaming/firewall connectivity, albeit with the following remarks:

   a. On a number of occasions the demonstration flights experienced problems with the accuracy (horizontal and vertical) and the availability of the tracker signal. These problems require further investigation.

   b. There must be a robust and easy to install solution for the integration of trackers on the drones.

7. A number of drone operators did not confirm the operational and technical acceptability of the current PODIUM U-space/UTM solution for the flight execution phase (corresponding to U2), with the following remarks:

   a. The use of a laptop for situational awareness "in the field" is not practical for the flight crew, and a handheld display would be a much better solution

   b. There is a strong preference amongst professional drone operators for an integrated flight control and U-space/UTM solution

5.1.1 Conclusions on maturity of the services/capabilities

As illustrated in Table 9, and taking into account the SJU guidance [23] , the PODIUM demonstration results are not totally in line with the assumption stating V3/TRL6 maturity of the U1 and U2 services and capabilities.

Concerning the U1 services addressed (e-registration and e-identification), drone operators, air traffic controllers and supervisors confirm the operational acceptability/feasibility and potential benefits of the current PODIUM U-space/UTM solution, albeit with a number of remarks as indicated at paragraph 5.1.

Concerning U2 services addressed, the air traffic controllers and supervisors confirm the operational acceptability/feasibility and potential benefits of the current PODIUM U-space/UTM solution for the flight preparation phase, albeit with a number of remarks as indicated at paragraph 5.1. A number of drone operators and pilots, however, did not confirm the operational acceptability of the current PODIUM U-space/UTM solution for the flight execution phase (corresponding to U2), in particular with regards to situational awareness aspects as explained at paragraph 5.1.

5.1.2 Conclusions on concept clarification

The CORUS Concept of Operation document [21] provides a good basis for conducting the demonstration in clarifying roles, actors and definition of services. The project mainly addressed operational and technical feasibility in the current U-space framework. The main points raised by the participants are related to more generic aspects, as part of the Concept of Operation: need for initial Cost Benefits Analysis, safety and security assessments, need for a European standard and regulation describing procedures/flight rules, data source, technical systems.

5.1.3 Conclusions on technical feasibility and architecture

The participants globally confirm the technical feasibility of the UTM system for flight preparation tasks. During the flight execution phase, some limitations/issues (e.g. loss of signal) of the tracking systems (including trackers, communication infrastructures) raised some concern during the flight execution phase. Being a crucial enabler of U2/U3 services (e.g. monitoring, conflict detection, geofencing), standardisation and regulation on trackers performance (accuracy, altitude, robustness) and communication infrastructure (e.g. latency of communication) were reported as key to ensure safe and efficient deployment of U-space services. The various systems also need to be interoperable when using data from difference sources.

5.1.4 Conclusions on performance assessments

From the human performance perspective, the results showed overall medium/high operational feasibility and acceptability of U-space services during the mission preparation phase (corresponding to U1 services). Drone operators strongly confirm the need and potential benefits for U-space/UTM solutions that ease the workload and reduce delays for acquiring drone flight authorisations. During the mission execution phase (U2 and U3), the operational feasibility and acceptability of U-space services was reported quite low. Drone operators, air traffic controllers and supervisors strongly confirm the need and the potential benefits for U-space/UTM solutions that improve situational awareness and communications to improve operational efficiency and maintain safety.

Improvements are also needed in terms usability/accessibility of the HMI and reliability of data to enhance trust in the system.

From the safety perspective, although the participants agreed potential benefits of the U-space services (e.g. geo awareness of the restricted area), it was reported as essential for pilots and supervisor to get the whole "air situation" while in flight. Indeed, the collaborative interface provided to Air Traffic controllers during Rodez demonstration greatly improved situation awareness and so reported as safety improvement.

From the security perspective, the main conclusion is the need for a formal, even generic, security assessment as part of the Concept of operation description. U-space should benefits from being a greenfield area to consider security of all assets (e.g. UTM, infrastructure) from the beginning.

5.2 Recommendations and requirements

This section outlines the main operational and technical recommendations emerging from PODIUM, as agreed by the consortium. They should be read as a "package" in conjunction with the recommendations and requirements on regulation and standardisation in the next section.

1. Ensure that U-space/UTM systems interact seamlessly and automatically with national systems for pilot and drone registrations, permission requests, etc.

2. Define the aeronautical data requirements and the associated authorities for drone operations in VLL airspace. Assess the suitability of NOTAMS to support drone operations (The work currently done by EASA for the development of AMC-GM to article 15 (geographical zones) of IR2019/947 is very relevant here).

3. Involve drone manufacturers, operators, air traffic controllers and supervisors in the design of the U-space/UTM human machine interface, with a view to maximising usability and accessibility.

    a. Optimise the interactions between the flight crew and the human machine interfaces for the (drone) flight controls and the U-space/UTM system during mission execution.

4. Strengthen situational awareness in the mission preparation phase for professional drone pilots and supervisors (with a view to handling conflicting flight paths, eventual violations, no-fly zones).

5. Strengthen situational awareness for professional drone operators in the mission execution phase by providing information about own flight, other flights in the area, no-fly zones, and unexpected events on a mobile application.

6. Define coordination procedures, phraseology and the means for ensuring reliable communications between the flight crew and supervisors/air traffic controllers. This is on the understanding that there is a need to mitigate against human and mobile phone limitations, including the need for training and education of operators.

7. Define operational procedures for drone flights entering a controlled airspace environment (CTR, airport) and for responding to abnormal situations (e.g. areas for stacking or emergency landings in the event of traffic conflicts, equipment failure).

8. Validate U-space/UTM performance for scenarios with increasing traffic density and complexity.
9. Promote "mini-UTM" implementations whereby local authorities can define additional local rules for drone operations and are able to respond to authorisation requests.

5.2.1 Recommendations and requirements on regulation and standardisation initiatives

10. Ensure that U-space/UTM systems provide drone operators with access to trustworthy and up-to-date aeronautical, national and local legislation data/rules. This is on the understanding that only "official" data should be used and that "open source" data – which risks to not comply with aeronautical data quality requirements - is not sufficient.
11. Determine the areas of operation for which drone tracking is required, and define the minimum standards for the trackers (i.e. accuracy, availability and RF interoperability) and their installation on board the drone. This is on the understanding that U-space/UTM systems must not degrade existing ATM surveillance systems, e.g. no degradation of the 1090MHz frequency for the RF link technology.
    a. Progress the standardisation of trackers, and allow for certifiable low power devices.
    b. Ensure the traceability between the drone registration ID and the tracker ID.
12. Perform airspace assessments to determine the level of U-space/UTM services and systems required in a particular airspace (The joint work of EUROCONTROL and EASA on airspace assessments for UAS operations is very relevant here) .
13. Develop a regulatory framework which maximises the granting of automated flight approvals for flights outside of manned controlled aerodrome environments.
14. Determine the rules for the safe handling of drone traffic with manned aviation, especially for BVLOS flights in uncontrolled airspace (The joint work of EUROCONTROL and EASA on flight rules for UAS operations is very relevant here).
15. Develop standards for equipment, software and data for which failure reduces safety to an unacceptable level.

5.2.2 Recommendations and requirements for updating the master documents

The PODIUM consortium has reviewed the U-space requirements baseline [24] and the resulting analysis has been provided separately to the SJU.

During an informal review of the demonstration report at the SJU premises on October 10, the SJU requested the PODIUM team to provide their view on the (i.e. U1, U2, U3, U4) in the U-space blueprint [27]. In response, based on the experiences of the demonstrations, the PODIUM team is of the opinion that:

- The U2 services applicable to the flight preparation phase (e.g. automatic flight plan validation) are currently at a higher level of maturity than those applicable to the flight execution phase (e.g. drone location surveillance and tracking).
- The U2 service for conflict detection and alerting currently has a low level of maturity, notably in the case of more complex scenarios involving multiple drone flights.

5.2.3 Recommendations and requirements for next phase

The ongoing SESAR U-space projects (Very large scale demo and exploratory research) are raising awareness, facilitating collaboration, and validating the current state of the art for U-space/UTM solutions. As mentioned in this section, PODIUM considers that significant actions and work are needed from the operational (e.g. increase scenario complexity and density), technical perspectives (e.g. tracker accuracy and availability), and standards/regulation aspects in order to move forward with deployment.

The PODIUM project is one of several large scale demonstration projects for U-space that are being performed within SESAR. The SESAR Joint Undertaking will consolidate the main findings of PODIUM and the other projects, in order to prepare a consolidated set of conclusions and recommendations for U-space at a “programme” level.

6 References

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[29] Drones Helsinki Declaration (22 November 2017)

[30] Denmark (Odense) Demonstration Report (edition 01.00.00, 30 August 2019)

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[32] France (Rodez) Demonstration Report (edition 01.00.00, 30 August 2019)

[33] Netherlands Demonstration Report (edition 00.01.00, 30 August 2019)

[34] Initial view on principles for the U-space architecture (edition 01.04, 29/07/2019)

Appendix A Trial Reports

Please refer to the individual site demonstration reports at [30][31][32] and [33].

Appendix B Human Performance assessment Report

PODIUM Human
Performance Assessı

Appendix C Safety Assessment Report

Objective

The objective of this safety assessment appendix to the consolidated PODIUM demonstration report is to provide an analysis of the safety related aspects observed during the extent of the PODIUM project in particular during the flight demonstrations along the different sites but also during the discussions with stakeholders and the review of the PODIUM documentation.

This appendix is not meant as a concise safety assessment of the full U-space set of services but a guidance for the future development and implementation of the concept.

Safety in the context of drone operations

The safety activities in the context of the drone flight trials exercises contemplates two different approaches.

1. Concept evaluation: Assessing U-space from a safety point of view at concept level in order to provide "Safety" requirements and recommendations
2. Safety not compromised: Assuring that safety is not compromised during the execution of the demonstrations (VLD)

Considering that the objective of PODIUM is to investigate the suitability of current and proposed U-Space solutions, the focus of this safety assessment section will be on the first area.

In relation with the safety not compromised aspect during the flight trials, the interactions between operators and local authorities have been one of the most relevant aspects. This activity has been addressed in each site-specific demonstration. The different local authorities and operators assured their specific trial complying with the required level of safety.

U-Space safety analysis

In order to perform the concept evaluation activity a holistic safety assessment approach for U-space concept is necessary. This holistic view is attained by considering two main points of view, a first one from the airspace assessment viewpoint and a second one taking into account the drone and operator perspective.

In relation with the risk determination, three areas of interest are proposed to assess the mitigation level provided by U-space services:

- Level of mitigation of air risk with U-space services in order to prevent collision between un-manned and manned aircraft.
- Level of mitigation of ground risk with U-space services in order to prevent fatalities on the ground and damage to critical infrastructure including aviation infrastructures like Control towers, Ground Navaids, Comm. antenna mast, etc.
- Level of mitigation of incursion into "no-fly zones" (airspace infringement) in order to prevent un-manned aircraft to penetrate into predefined airspace/areas

To assess the risk related to these areas of interest have been taken into account aviation hazards (pre-existing risks), external events and possible system-generated hazards to determine the safety recommendations for drone operations supported by U-space services.

U-Space Broader Safety approach

The high dependence of U-space in automation and new emerging technologies obliges to have a "broader" safety approach in contrast to other classical methodologies. Assessing how reliable the U-Space (as a combination of equipments, procedures and human resources organised to perform a function within the context of U-Space) needs to be in order to ensure an adequate protection against internal failures of the system's elements does not seem to be sufficient to demonstrate that drone operations supported by UTM systems will be safe. The U-Space cannot be only seen just as a combination of equipment, technological solutions, procedures and human resources instead of the organization and interaction of all these elements performing a function. Additionally the interfaces that make possible the interconnection with manned ATM system have to be taken into account.

Assuming that the U-Space is intrinsically safe when no failure occurs is not a valid argument for a new concept of aviation that will rely mainly in technology and automation and where the level of safety has to be commensurate to the risk level. Consequently, a safety assessment for the U-Space concepts will require examining the so-called "success based approach" in addition to the internal system failures (termed "failure based approach").

- Firstly, a success approach in which it is assessed how effective the new concepts and technologies are when they are working as intended – i.e. how much the aviation risks that are already inherent to unmanned aviation will be reduced by the U-Space operations and services put in place. This is concerned with the positive contribution to aviation safety that the U-Space concept introduction make in the absence of failure.

- Secondly, a failure approach in which it is assess the U-Space system generated risks, i.e. induced by the U-Space services and operations failing. This is concerned with the negative contribution to the risk of an accident that the U-Space concepts might make in the event of failure(s), however caused.

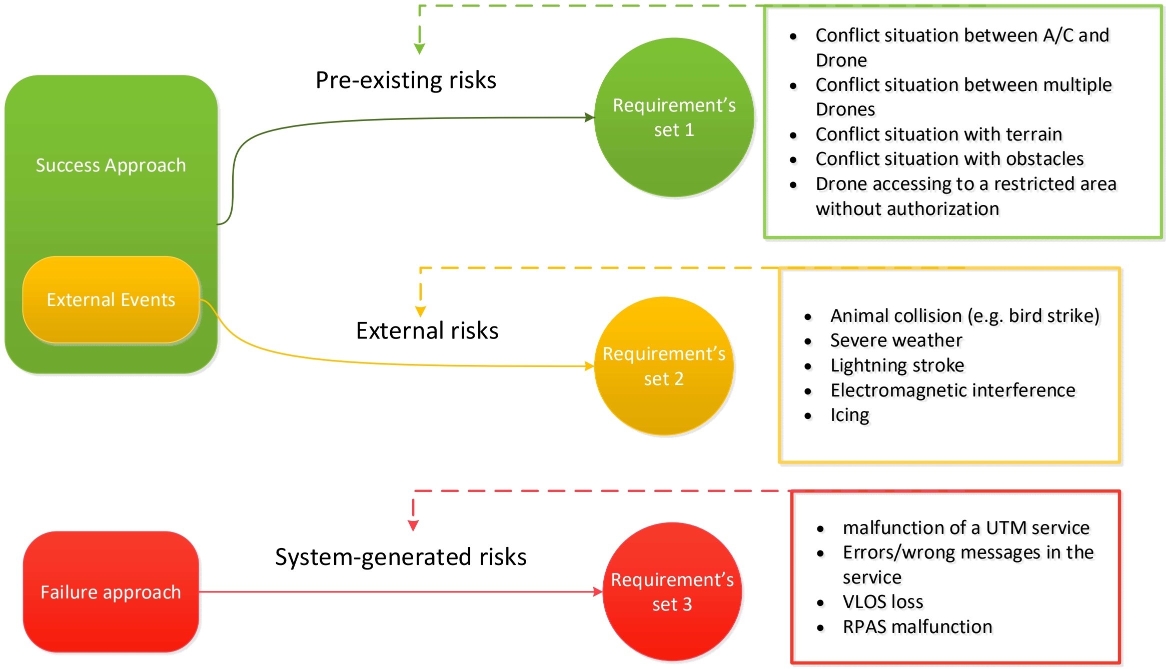

Figure 24: Possible U-Space risks' derivation from success and failure approaches

Safety Concept Evaluation

As previously mentioned the evaluation of the concept has been the main goal of the safety assessment and assurance activities within PODIUM. In order to support the evaluation of the concepts the following activities were performed:

1. Determination of the safety measures to be collected during trials
2. Matching the safety measures with the U-space services implemented for each trial (What can be measure, where and how, i.e. through what service/s)
3. Finding how the U-space service/s will capture the appropriate safety measures
4. Collecting qualitative data from the different trials (In form of feedback and questionnaires)
5. Analysing the data and deriving recommendations for the U-space

The safety activities did not focus in the collection of the data, which was performed by the different partners at the demo sites, but rather in determining the safety measures and its subsequent analysis.

Safety Measures to Assess the Concept Evaluation

The following safety measures were proposed and analysed to determine the maturity of the concept in terms of safety:

- Separation between drone and other possible airspace user (Horizontal and vertical)

- Means to determine drone's altitude

- Deviation of the drone from its intended trajectory (Intent compliance level)
- Level of information provided about no-fly zones (geofencing service)
- Proximity to no-fly zones (geo-fenced areas)
- Unusual/Unexpected distance between drones and obstacles

Safety Assessment Conclusions and Concept Evaluation

The analysis of the safety measures collected during trials in a qualitative way, taking into account the principles of the broader safety approach, demonstrates the contribution of the U-space services to drone operations in the following way:

- How UTM systems increases safety levels by provision of appropriate data from pre-flight to post-flight phases.
- Showing the contribution of the U-space services to limit air risks in VLL airspace.
- Showing the contribution of U-space services to limit ground risks.
- Demonstrating the capability of U-space services to decrease the risk of penetrating no-fly zones.

This increase in the safety level produced by the U-space services has been shown through the usage of the UTM platform by the participants and their feedback provided before, during and after the operations. As a result, the air-risk has been effectively mitigated by the implementation of the tracking systems and the HMI interfaces allowing segregation with manned traffic. The pre-flight tools utilized allowed to mitigate the air-risk by proportioning strategic de-confliction and situational awareness of possible conflicts routes of surrounding traffic. During the execution of the drone flights the services deployed allowed to perform conformance monitoring with the involved traffic which allowed to reduce sensibly the risk of collision in the air.

The ground risk has been effectively mitigated as well. On one hand in the pre-flight phase by the mission preparation supported by the UTM platform minimizing this risk by avoiding populated areas and critical infrastructures. On the other hand, during the flight execution phase the usage of the tracking system and HMI interfaces permitted to monitor and avoid in case of necessary possible unforeseen conflicts/obstacles. Post-flight data captured during flights appropriately processed could additionally contribute to mitigate ground risk for posterior flights in the respective flight volumes/areas.

Moreover, no fly zone infringements has occurred neither situations that could induce a breach into a no fly zone or proximities to those due to the appropriate situational awareness of pilots, controllers and supervisors provided by the system in relation to these areas.

In general, the system contributes to augment the situational awareness of all participants involved in the demonstrations at different levels; in particular, increasing the possibilities for conflict detection/alerting and flight mission update during the flight services execution. This is seen as a positive step for the U-space services deployment to ensure and progressively increase safety in todays and future operations.

Nevertheless, certain drawbacks have been observed in the system to its contribution to the safety of the operation. These weaknesses detected come from the following issues:

- The situational awareness is not uniform among all actor being the drone pilots the most limited ones in this aspect. They reported certain lack of awareness to avoid obstacles and/or other airspace user as could be general aviation users.
- The tracking systems have still a considerable number of limitations that need to be overcome to permit routine operations in non-segregated airspace. For instance, the altitude provided by the tracker needs to be provided in an accurate and reliable manner. Improvement in the internal algorithms supporting the tracking and additional tools for conflict detection and alerting based on further experience are needed. Inclusion of the general aviation in the “air picture” to facilitate the effective separation of all airspace users.
- There is a lack of common reference altitude for UAS, which contributes to the lack of a standard altitude in the tracking systems and the appropriate standard phraseology during communications.
- Absence of standardization for flight rules and contingency measures as fall-back procedures or loss of communications.
- There are no rules concerning separation both horizontally and vertically. Separation rules must be defined for both UAV vs UAV and UAV vs crewed aircraft. Higher efforts in this field have to be taken for the implementation of effective separation procedures and tools allowing automatic conflict detection and conflict resolution.
- Limitations observed with regards of conflict detection rules/algorithm.
- Lack of standards related with the available information used and provided during mission preparation and flight approval. Furthermore, the data utilized in the UTM system is desirable to be based in precise data coming from reliable sources in the best of the cases having being verified by a certification process.
- Limitations of the system to allow a risk based approach (i.e. level of performance commensurate to the level of risk). It is considered convenient the possibility to offer different levels of performance of the system depending on the risk level of the mission. This would involve different the accuracy level of the tracking, level of communication, variable level of service provision to different airspace users, etc.
- Other technical requirements related with the accuracy of the system.

The aforementioned limitations are expected to be overcome in some measure after further industrial development steps that will allow producing and analysing bigger amounts of reliable data. These data will permit precise quantification to populate safety models, appropriately designed for U-space operations, granting that way the complete maturity of the U-space services at all levels.

Finally, the questionnaires distributed among the participants during the demos (Drone pilots and supervisors) showed the perception on the safety variation in the operations supported by the U-space services in comparison to the absence of these. The safety perception among the demonstrations stakeholders has been assert as positive with support of U-space services. The survey distributed has identified a positive impact to the operations' safety of the UTM system. Globally, most of the participants reported that the UTM system could potentially improve the current level of safety. Pilots and supervisors foresaw an increased situation awareness through the availability of current "air situation" shared among all the parties.

Safety Recommendations

In order to achieve an acceptable level of safety when U-space operations become a daily routine when the UAVs traffic grows to the forecasted level for the coming years and as a result of the trials performed during the PODIUM demos, the following recommendations are proposed for future activities:

1. The need of the definition of a common reference altitude for UAVs
2. Definition of standard phraseology during communications for U-space operations
3. Definition of standardized flight rules and separation minima distances (both horizontally and vertically).
4. Definition of standard contingency procedures (Fall-back site/ forbidden landing sites, loss of communications procedures, etc.)
5. Further development of effective tools allowing automatic conflict detection and conflict resolution with respective associated procedures.
6. Definitions of standards for the information provided during mission preparation and flight approval. Information based in precise data from reliable sources at best derived from a certification process is recommended.
7. Homogenise the situational awareness of all actors involved in U-space operations, in particular for drone pilots to be able to avoid obstacles and being able to "see/detect" other airspace users (including general aviation users).
8. For non-segregated operations between manned and unmanned aircraft, the usage of tracking systems based in accurate data is strongly recommended. The integration of the tracking for U-space operations together with manned aviation, which serves to align the U-Space safety activities with the ATM/ATS safety activities where appropriate.
9. Tracking systems for drones to be further developed in terms of internal algorithms supporting the tracking and additional tools for conflict detection and alerting. Inclusion of the drone altitude during the tracking coming from standardized reliable sources. Inclusion of the general aviation in the "air picture" to facilitate the effective separation of all airspace users.
10. Assessing the risk of particular U-space operations based in a holistic safety approach by incorporating different viewpoints as the airspace perspective (airspace design, ATS provision, U-space service provision, interoperability, etc.) together with the operator perspective (air operation, airworthiness, etc.). This should be achieved by developing and making use of Integrated Risks Models that provide a structured breakdown of the drone

accidents causes, with particular emphasis on U-Space service provision contributions (both positive and negative).

These recommendations might be transferred to requirements depending on the level of safety required by each type of operation; this is based on a risk-based approach, supported by U-space services. In the beginning and with the idea of not being prescriptive defining specific requirements, all of them have been formulated as recommendations instead of setting imperative principles for the U-space deployment.

Appendix D Security assessment Report

Objective

The objective of this security related annex to the consolidated PODIUM demonstration report is to give an overview of security related observations during the review of the PODIUM documents, discussions with stakeholders and flight demonstrations.

It is not meant as a concise security assessment of the U-Space service

Security in a Drone Context

Security in the context of drone operations can be divided into two areas:

1. Security issues caused by malignant use of drone technology (e.g. using drones for spying or attacks on persons or goods).
2. Security issues caused by attacks on the drone infrastructure with the aim of disrupting the orderly execution of drone operations.

Given the fact that the objective of PODIUM is to investigate the suitability of current and proposed U-Space solutions, the focus of the security section will be on the second area.

U-Space analysis

U-space

Drone operation in general and in the context of U-Space are highly dependent on automation and interconnected systems. The U-Space services are intended to be easily accessible by the drone operators. This means that it has a larger attack surface than for instance Air Traffic Management systems. Since this is inherent to the intended mode of operations, the open character of the U-Space services have to be accepted and the necessary steps need to be taken to assure secure operations.

Analysis method

The method chosen for the PODIUM security analysis is asset based. This is currently the most common way to perform a (cyber)security analysis of systems in ATM. Given the similarities between ATM and UTM, the asset based method is likely to produce results comparable to ATM security analyses.

The method is based on the identification of primary assets, which are main assets to be protected. They are, in general, intangible constituents of the system like services, processes, and information.

These primary assets depend on a set of supporting assets, which are in contrast quite tangible. Examples are humans, computers, buildings, but also software and procedures.

The basic idea behind this approach is to identify and mitigate the vulnerabilities that can be found in the supporting assets and thereby protecting the primary assets.

Primary assets

The primary assets that comprise the U-Space service are:

1. Airspace management
2. Flight plan handling
3. Flight authorisation
4. Flight monitoring
5. Mission management

The first observation about the primary assets is that they are not yet stable. In fact, they are not even defined in a concise way. This is in line with the current state of U-Space, which is still in a fairly early stage of development.

In fact, this is a risk as well as an opportunity. The risk is that, like in many other new development areas, security does not have a high priority. The focus of development is on providing the functionality that is required to operate drone missions in an efficient way. Since security normally imposes limitations, it is tempting to postpone it to later stages of the project. In addition to this natural behaviour, the size and fragmentation of the U-Space project makes it difficult to define a structural and harmonised approach to security.

Although understandable, it may become a missed opportunity. As we see in the ATM world, retrofitting security mechanisms into existing systems is far more difficult and expensive than introducing them from the start.

Since security is a chain, where the strength is determined by the weakest link, it is highly recommended to define and implement security requirements from the beginning throughout the whole spectrum of U-Space services.

Supporting assets

As is the case with the primary assets, the supporting assets are also in their early development stages and security is not the primary concern. It must be said, though, that the discussion with Unifly about their software approach revealed that they have taken security into account from the beginning and their software uses state-of-the-art security mechanisms. This, however, seems to be the result of local initiative rather than of a system wide approach to security.

One of the major differences between the U-Space (UTM) and ATM domain is the extensive use of the Internet in the former. Although the basic security assessment principles used in ATM can be re-used, the exposure risk attack probability in case of U-Space will be larger. This does not necessarily mean that the overall risk is larger as well, since—at least for the moment—the impact will generally be lower than in case of commercial aviation.

Since the U-Space world is practically a greenfield area, it can be used to introduce and validate new security mechanisms, that could be transposed to the ATM world. In addition to the needs for U-Space (cyber-)protection, this could be a second valid reason to invest in cybersecurity from the beginning.

It should be noted as well that—in case U-Space services are directly connected to the ATM infrastructure—a new attack vector for ATM is introduced. This needs to be taken into account in defining security requirements for U-Space.

The main supporting assets in U-Space are:

- UTM system (e-registration, e-identification, geofencing, mission support)
- Communications infrastructure

- Surveillance sensor infrastructure
- Navigation infrastructure (GNSS)

In principle, the operators of the infrastructure components are responsible for the (cyber-)security assurance of their primary and supporting assets.

Since there is a clear hierarchy in drone operations, the requirements should come from the top and the information about the risk assessment and mitigations should be provided from the bottom.

As shown in the figure, at the top of the hierarchy, there are the drone operations. Regulations applicable to drone operations and the operational requirements should drive the top level security requirements. They would affect all areas shown in the figure.

At the next level the UTM services are located. The UTM services would rely on the surveillance and communications services. If the surveillance data is provided by the UTM to the drone operator, the latter would not have any direct dependency on the surveillance data. If other providers are used, there would be an arrow from surveillance to the drone operations.

Both the drone operator as well as the UTM service provider, would be dependent on the communications infrastructure.

Recommendations

Once drone operations start to become an economic factor, it will attract different types of perpetrators and the risk will increase rapidly. In order to be prepared, a number of steps to be taken from the initial steps of development and operations are recommended:

1. Define security requirements and regulations for the identified primary and supporting assets.
2. Create oversight mechanisms for all elements in the chain (including those of the service providers, software developers and drone manufacturers).
3. Integrate a formal security assurance process into the ConOps.
4. Integrate a formal cybersecurity assurance process into the development and infrastructure operations processes.
5. Align the U-Space security activities with the ATM security activities where appropriate.
6. Integrate basic security awareness into the drone pilot training.

Appendix E PODIUM U-space Services in Relation to Master Plan Roadmap U-space Services/Capabilities Described by CORUS

X	PODIUM fully or to great extend covers service/capability described by CORUS
X	PODIUM partly covers service/capability described by CORUS
	PODIUM services tested during the demonstrations

U-space Roadmap Services& Capabilities\ PODIUM Services	E-identification	Registration	Drone location surveillance and tracking	Automatic Flight Plan Validation	Automatic, manual Flight permissions	Generation and management of no-fly zones that become active while the drone is in flight	Geo-awareness	Generation and management of no-fly zones based on aeronautical information (including NOTAMs) and aviation regulations	Generation and management of no-fly zones for non-aeronautical reasons by appropriate agencies	Geofencing and Geocaging	Monitoring of compliance of the drone operations with relevant rules and regulation	Conflict Detection / Alerting	Post-flight services	UTM/ATM Interoperability
Identification and Tracking														
U-1 Registration		X												
U1/U-2 Registration Assistance		X												
U-1 e-Identification	X													
U-2 Tracking (Position report submission)			X											
U-2 Surveillance Data Exchange			X											
Airspace Management/Geo-fencing														
U-1 Geo-awareness						X	X	X	X					
U-1 Drone Aeronautical Information Management								X	X					
U-2 Geo-fence provision (includes Dynamic Geo-fencing)						X				X				
Mission Management														
U-2 Operational plan preparation/optimisation				X	X									
U-1 Operational Plan processing				X										
U-2 Risk Analysis Assistance														
U-3 Dynamic Capacity Management														
Conflict Management														
U-2 Strategic Conflict Resolution				X										
U-3 Tactical Conflict Resolution														

U-space Roadmap Services& Capabilities\ PODIUM Services	E-identification	Registration	Drone location surveillance and tracking	Automatic Flight Plan Validation	Automatic, manual Flight permissions	Generation and management of no-fly zones that become active while the drone is in flight	Geo-awareness	Generation and management of no-fly zones based on aeronautical information (including NOTAMs) and aviation regulations	Generation and management of no-fly zones for non-aeronautical reasons by appropriate agencies	Geofencing and Geocaging	Monitoring of compliance of the drone operations with relevant rules and regulation	Conflict Detection / Alerting	Post-flight services	UTM/ATM Interoperability
Emergency Management														
U-2 Emergency Management												X		
U-2 Incident/Accident reporting													X	
U-2 Citizen Reporting service														
Monitoring														
U-2 Monitoring							X				X	X		
U-2 Traffic Information														
U-2 Navigation Infrastructure Monitoring														
U-2 Communication Infrastructure Monitoring														
U-2 Legal Recording													X	
U-2 Digital Logbook													X	
Environment														
U-2 Weather Information				X	X									
U-2 Geostatical Information service														
U-2 Population Density map														
U-2 Electromagnetic interference information														
U-2 Navigation Coverage Information														
U-2 Communication Coverage Information														
Interface with ATC														
U-2 Procedural interface with ATC											X			X
U-3 Collaborative interface with ATC														X

Table 11: PODIUM-CORUS Services Matrix

The list of CORUS services and their descriptions considered are corresponding to the services description in CORUS ConOps v01.01.03.

The following paragraph highlight the main differences/similarities between PODIUM and CORUS services definition.

E-Registration: In PODIUM demonstrations all drones are electronically registered in the PODIUM DTM System. The registration includes drone operator, drone pilot, drone and its specific equipment. E-registration processing PODIUM takes place prior to the operations.

Identification: in PODIUM demonstration every drone during its flight emits drone identification correlated with its registration.

Drone location surveillance and tracking: PODIUM drone location surveillance and tracking service corresponds to CORUS U-2 Tracking (position report submission) service. Several different trackers will be used in the demonstrations and will be displayed in the PODIUM interface.

Automatic Flight Plan Validation: This PODIUM service allows drone operators to submit a flight plan. Flight plans have to be submitted prior to the operation via the PODIUM interface. PODIUM DTM System validates a flight plan and provides a response (either acceptance or rejection) to a submitter. Only accepted flight plans can be flown. In case of rejection, the operator has the possibility to re-submit a flight plan with the necessary changes in order to full fill airspace and operational requirements.

Every submitted flight plan has a unique identifier. Therefore, every flight can be recognised and distinct in PODIUM demonstrations.

An additional task of the flight plan validation is to check if the planned route crossed a geofenced area (in this case the flight plan shall be rejected).

Moreover, some initial pre-tactical de-confliction (in CORUS U2 service: Strategic Conflict Resolution) will be performed (based on the flight planning possibilities to approve/reject flight plans with possible overlaps in area/time of flights)

Automatic, Manual Flight permissions: PODIUM DTM System flight permissions service represents partly CORUS Mission Management U-space services, more specifically U2 Operational plan preparation/optimisation. This includes the provision of an interface with ATC, National and Local authorities. In PODIUM demonstration the role of the service is more relevant to the pre-flight state and involves various authorities & stakeholders in the service.

Generation and management of no-fly zones those become active while the drone is in flight: The service is part of CORUS U1: Geo-awareness service. The service provides the information on no-fly zones (both aeronautical and non-aeronautical) before the flight has commenced. This allows drone pilots to become aware if there are no-fly zones which are in the vicinity of the area of potential operation before the flight.

Prevention of the drone from flying inside the defined no-fly zones, including those that change during flight: PODIUM partly covers this CORUS U-2 Geo-fence provision (includes dynamic geo-fencing). PODIUM service will provide the information on no-fly zones and will send messages to drone pilots when the drone is in the vicinity of a no-fly zone and may be entering such a zone.

Generation and management of no-fly zones based on aeronautical information (including NOTAMs) and aviation regulations: This PODIUM service is part of CORUS U-1 Drone Aeronautical Information Management. The PODIUM service includes all information coming from AIP and NOTAMS and makes it available for drone pilots via the PODIUM interface.

Generation and management of no-fly zones for non-aeronautical reasons by appropriate agencies: This PODIUM service is part of CORUS U-2 Drone Aeronautical Information Management. It includes all information coming from non-aeronautical sources (for example information provided by local authorities) and makes it available for drone pilots via PODIUM interface.

Geofencing and Geocaging: The PODIUM DTM service will support generation and activation/deactivation of geofenced and geocaged areas.

Monitoring of compliance of the drone operations with relevant rules and regulations: PODIUM Monitoring service is a service that can provide traffic information for each specific flight and review if the flight complies with relevant rules and regulations. PODIUM Monitoring of compliance of the drone operations with relevant rules and regulation corresponds to CORUS U-2 Monitoring Service and partly CORUS U-2 Procedural interface with ATC.

Conflict Detection / Alerting: PODIUM Conflict detection and Alerting partly covers CORUS U-2 Emergency Management service. The PODIUM service allows to detect a possible conflict and alert pilots involved.

Post-flight services: PODIUM post-flight services includes a possibility to create a flight log and to file an incident/accident report (therefore it's partly covering CORUS U2: Incident / Accident Reporting service).

DTM/ATM Interoperability: the PODIUM DTM/ATM Interoperability service allows ATM and DTM to interact with each other on different stages of flight (including flight plan checking in case of flights in controlled airspace, drone monitoring, notification in case of a drone entering controlled airspace, etc.). This service corresponds to CORUS U-2 Procedural interface with ATC and U-3: Collaborative interface with ATC[3]

[3] As CORUS does not provide a detailed description of U3: Collaborative interface with ATC service, it is assumed that PODIUM will cover the service.

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