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Authoring & Approval

Authors of the document

Name/Beneficiary	Position/Title	Date
Janus Bill Andersen/INTEGRA AERIAL SERVICES	WP4.1 Leader	20.08.2019
Renée Pelchen-Medwed/EUROCONTROL	Human Performance expert	20.08.2019

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
Peter Alty/EUROCONTROL	Project Coordinator	22.08.2019
Renée Pelchen-Medwed/EUROCONTROL	Human Performance expert	22.08.2019
Jakob Jensen Prühs/NAVIAIR	UTM Manager	27.08.2019
Jens Christian Skinneholm/NAVIAIR	M.Sc. Civil Engineering	27.08.2019
Steen Myhre Taschner Erichsen/ NAVIAIR	Head of UTM Development & Strategy	27.08.2019
Dennis Bollen/Unifly	Business Analyst/Project Manager	28.08.2019
Tobias Lundby/Unifly	Technical Business Analyst	28.08.2019

Approved for submission to the SJU By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
Jakob Jensen Prühs/NAVIAR	UTM Manager	30.08.2019
Gilles Fartek/INAS	Project member	30.08.2019
Dennis Bollen/Unifly	Project member	30.08.2018
Alexandre Piot/Airbus	Project member	30.08.2018
Tom Sorgeloos/Orange	Project member	30.08.2018

Rejected By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date

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PODIUM

PROVING OPERATIONS OF DRONES WITH INITIAL UTM

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Abstract

The Proving Operations of Drones with Initial UTM (PODIUM) is a SESAR/Horizon 2020 Very Large Scale Demonstration Project, which demonstrates U-space services, procedures and technologies across five sites in Denmark, France and the Netherlands. This document is the site demonstration report for Denmark describing the work performed, the main results, and most important conclusions and recommendations.

The trials in Denmark were carried out in the UAS test center of Hans Christian Airport and comprised 23 individual flights covering 5 different scenarios, which aimed at testing the U-space services in multi-mission scenarios operated in VLL, urban and in class G airspace from ground level up to 3500ft. The scenarios should reflected the conduct of drone operations as VLOS, BVLOS and VFR operations, which have already been executed or are expected to be daily routine in the near future.

The demonstrations and subsequent analysis of the systems and related trackers and procedures to some extent is clear and acceptable in a U-space framework despite having some challenges concerning the software and HMI. During the tests, it was found that flight planning and gaining permissions via the UTM system proved sufficiently mature, while some consideration must be given to the flight execution part of the system – primarily for the drone pilots, while the supervisor-entry proved more developed.

The contents of this individual site demonstration report will form part of the overall Demonstration Report for PODIUM, which the project plans to make available by September 27 prior to a dissemination event at EUROCONTROL Brussels on October 17.

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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, which demonstrates U-space services, procedures and technologies across five sites in Denmark, France and the Netherlands. This document is the site demonstration report for Denmark describing the work performed, the main results, and most important conclusions and recommendations.

The trials in Denmark were carried out in the UAS test center of Hans Christian Airport and comprised 23 individual flights covering 5 different scenarios, which aimed at testing the U-space services in multi-mission scenarios operated in VLL, urban and in class G airspace from ground level up to 3500ft. The scenarios should reflected the conduct of drone operations as VLOS, BVLOS and VFR operations, which have already been executed or are expected to be daily routine in the near future.

The demonstrations and subsequent analysis of the systems and related trackers and procedures to some extent is clear and acceptable in a U-space framework despite having some challenges concerning the software and HMI.

During the tests, it was found that flight planning and gaining permissions via the UTM system proved sufficiently mature, while some consideration must be given to the flight execution part of the system – primarily for the drone pilots, while the supervisor-entry proved more developed.

Furthermore, it is speculated if U-space services would be an add-on to existing systems or be an integral part of the national and European legislation. In the latter respect, it would be apt to speculate in the integration of systems into drones and drone software and centralise supervisor roles.

From the demonstrations and analysis, the high-level requirements for a UTM system were:

- System shall indicate what documentation is additionally needed for BVLOS to avoid additional requests (clear visibility on what information is needed for what mission-local)
- It shall be possible to locate pre-planned flights even if the scheduled takeoff time has passed before the drone actually takes off
- Drone shall be visible on pilot view map
- Possibility to communicate via the App (e.g. being told when the flight is approved or rescinded etc.)
- The system should be able to be used simultaneously (integrated) with the drone software to accommodate one-person mission
- Information about no-fly zones, other planned fly-zones, weather forecast, altitude of the drone, location of the drone and warnings about unexpected events shall be available
- The system shall notify the pilot if the flight permission was cancelled by the Supervisor
- The integration of regular aircraft and drone traffic should be highest on the agenda

- A reliable system and trackers that turn on automatically when the drone is turned on. Tracker and UTM system go hand in hand.
- Tool usage in connection with emergency service has still to be investigated as emergency service have time critical missions
- Procedures (and technical implementation) for faulty trackers have to be defined
- Procedures/Phraseology between Supervisor/ flight crew/AFIS have to be defined (e.g. if Supervisor notifies about another drone in the area)
- BVLOS permission request has to be improved
- Training campaign has to be planned

The demonstrations were mainly led by Integra but with invaluable help from various stakeholders along the way e.g. NAVIAIR, Unifly, Hans Christian Andersen Airport, University of Southern Denmark (SDU), The Danish Transport, Construction and Housing Authority and UAS Denmark. Furthermore, the demonstrations could not have been conducted without the help of a handful of drone pilot and stakeholders from the Greater Copenhagen Fire Dept. and the Police dept. of Funen who gave their time, knowledge and opinions on the maturity of the system for the various types of uses today and in a near future.

In Denmark, the system has been tested beyond its capabilities at the time, which are being implemented as we speak. No doubt, we are at an early stage of UTM systems for U-space purposes, but the future for increasing air safety with drones as an added feature looks promising. With the continuation of developments of the technologies, UTM based on the U-space guidelines could become the biggest breakthrough within aviation in Europe and worldwide for many years.

The contents of this individual site demonstration report will form part of the overall Demonstration Report for PODIUM, which the project plans to make available by September 27 prior to a dissemination event at EUROCONTROL Brussels on October 17.

This individual site demonstration report does not take into account the Guidance for U-space recommendations and conclusions [3]. PODIUM will, however, take this guidance into account for the development of the overall demonstration report.

Appendix AEXE-VLD-ODE-001: Enhancing drone interface with aviation environment

This appendix provides the demonstration report for the demonstrations as planned in the PODIUM VLD Revised Demonstration Plan [1].

A.1 Summary of the Exercise Plan

A.1.1 Exercise description, scope

The demonstrations in Odense was conducted during six days comprising 5 multi- mission scenarios covering operated in VLL (Very Low Level) airspace, urban and in class G airspace from ground level up to 3500ft. The scenarios reflected the conduction of drone operations as VLOS, BVLOS and VFR operations, which are already executed or expected to be daily routine in the near future. The intention was to involve the demonstration representative of the general aviation community as airspace users in order to create the conditions of normal operations in reserved airspace, with de-conflictions ensured by geographic, time and airspace block segregation. Furthermore, the demonstrations aimed at devising simulated scenarios that are similar to everyday operations outside airport restriction areas to give an impression of how UTM services would take place in the above-mentioned airspaces that are already occupied by professional drone pilots on ordinary terms and conditions.

Figure 1 PODIUM visitors day at Odense

The PODIUM DTM/ATM interface should facilitate situational awareness for all involved stakeholders via different communication means and different kinds of communications. By involving HCA Airport into the process, it was possible to involve the aerodrome flight information service (AFIS) in airspace class G. The Danish authorities (police, defence, CAA, Odense Municipality) and AFIS supervisors were invited and participated to some extent actively in the demonstrations in HCA airport in Odense to operate the UTM system.

The main intention was to demonstrate the usability and relevance of the UTM tool, and in particular with regards to flight planning, real-time information of on-going drone operations (flight intentions, contact information etc.), notifications of drone operations, setup of ad-hoc no-fly-zones, approval of drone operations in limited-fly-zones, communication via C2 link to the remote pilot, etc. A mobile application would give participants in the field an overview of drone operations and an opportunity to communicate with the supervisor, drone pilots and other relevant actors if needed.

The second intention was to demonstrate the added value that the system provides to other drone operators flying in the vicinity, as well as to other airspace users involved in the demonstration phases.

The exercise consisted of several drone flight scenarios conducted within the Odense airport's airspace from close April until close May 2019. It mainly involved drone pilots operating fixed wing and multi rotor drones in VLOS and BVLOS flights through the Unifly UTM system. Furthermore, the demonstrations included a scenario with the involvement of general aviation to test the possible benefits to be brought for the safe interaction between drones and manned aviation.

It was also discussed to test the possibility of using the Tower Simulator at Integra, in order to perform evaluation of coordination between drone operators and AFIS, for specific elements to be defined during WP 4.2 phase. However, this never came about why it will not be discussed any further.

Besides the original objectives, additional objectives were added during the development of the scenarios as there was a notable wish from various Danish Stakeholders and Eurocontrol to make assessments of the system's ability to cope with traffic patterns of the near future. That implied pushing the system to the limit, and practically it involved adding the following objectives to the Danish demonstration flight:

- Assess the use of SDU trackers on larger vehicles going above the maximum altitude of conventional unmanned aircraft for the investigation of GSM based technology on near-future long-haul drone flights.
- Get feed-back on the use of tracker technology as part of a mandatory equipment for BVLOS flying drone platforms in an already proven scenario with the information and ability for drone pilots and supervisors to monitor while in-flight.

Services used

The demonstrations at Odense used the following services as described at chapter 9 of the PODIUM Concept and Architecture Description [2]:

- E-registration (9.2.1)
- E-identification (9.2.1)
- Drone location surveillance and tracking (9.2.2)
- Automatic and manual flight permissions (9.2.4)
- Generation and management of no-fly zones (9.2.5, 9.2.7, 9.2.8)
- Geoawareness (alerting the drone flying close to the defined no-fly zones, including those that change during flight) (9.2.6)
- Conflict detection and alerting (9.2.11)

With the above-mentioned tasks to be performed, it was important to assign roles and responsibilities for each party involved ranging from observer through drone pilot to supervisor. This meant that the tasks were easily assigned and demonstrations could be conducted with ease as everyone knew their specific task in the setup, why few questions were asked regarding what to do.

Pre-flight phase:

- The pilot was registering the drone

- The pilot identified the tracker
- The pilot and observer had to fill the pre-flight checklist
- Was planning his flight by inserting it into the UTM system
- Asked for validation of his flight plan
- The Observer supported the pilot in his tasks
- The Supervisor was informed about the flight plan (validated via the system)
- The Supervisor inserted no fly zones in the system

Mission execution phase:

- The pilot flies the drone and observes it on the drone system
- The Observer communicates with the supervisor and with the person in charge of communicating with the tower
- The Observer communicates with the pilot
- The observer indicates to the system when the drone starts and lands
- The Supervisor monitors the drone on the UTM system
- The Supervisor communicates with the observers and the person in charge of the communication with the tower (formalised through normal radio procedures)

The demonstrations at Odense used the following systems as described at chapter 9 of the PODIUM Concept and Architecture Description [2]:

- Types of drones used:
  - Multi-rotor:
    - DJI Inspire 1
    - DJI Inspire 1 Pro
    - DJI Matrice 600 Pro
  - Fixed-Wing
    - Parrot Disco FPV
    - Sky-Watch Cumulus V1 BVLOS updated version provided by SDU
    - Integra purpose-built drone based on Chinese airframe (MUGIN): 3.5 m wingspan
- General aviation aircraft
    - Cessna T182R Turbo Skylane - OY-FCJ from Odense Parachute Club
- Unifly UTM system
  - Sentry (Supervisor tool)
  - Unifly Pro (Drone operator/pilot role)
  - Unifly Launchpad (Handheld application)

- Airbus
    - U-space surveillance Tracker and Server (URTAS) for fusion
    - Integrated Controller Working Position
    - Recording

- Orange Access Point Name connectivity

- Trackers
    - DroneID SDU GSM-based

A.1.2 Exercise Objectives and success criteria

The table below presents the objectives and success criteria defined in the Revised Demonstration Plan [1].

Demonstration Objective	Demonstration Success criteria	Coverage and comments on the coverage of Demonstration objectives	Demonstration Exercise Objectives	Demonstration Exercise Success criteria
OBJ-VLD-POD-001 Operational feasibility and acceptability	CRT-POD-001-001 CRT-POD-001-002 CRT-POD-001-003 CRT-POD-001-004	Partially covered	For all scenarios, the usability of the U-Space system in a real operational context, in nominal, non-nominal and degraded situations is optimum. Demonstrations for scenarios 003 to 005 that required efforts for using U-Space system are not too constraining. Demonstrate that training and transition needs are identified and documented for all future users. For all scenarios, the system proposed fits the technical users' needs. Demonstrate performance of the system for all users, in nominal, non-nominal and degraded situations.	The usability of U-space services is maximised for all stakeholders, in any condition, and at all phases of the scenarios. The use of the UTM system by drone pilots in operation does not impact its capability to perform operations. The knowledge transfer is easy for all stakeholders using the system. Measurement of the level of usability and acceptance of the technical systems proposed to the end users. Level of usability and acceptance of technical systems matches expectations for all phases of the scenario and for all conditions.

Demonstration Objective	Demonstration Success criteria	Coverage and comments on the coverage of Demonstration objectives	Demonstration Exercise Objectives	Demonstration Exercise Success criteria
OBJ-VLD-POD-002 Technical feasibility	CRT-POD-002-001 CRT-POD-002-002 CRT-POD-002-003 CRT-POD-002-004	Partially covered	Demonstrate UTM system capability to provide required information for U-space services. Demonstrate UTM system capability to provide expected services for all U-space services in complex operational environment. Demonstrate that SWIM infrastructure supports all U-space services. Demonstrate interoperability of various systems (e.g. trackers, data recorders, aeronautical data, displays) providing expected U-space services to end users.	For conducting their respective tasks, all stakeholders receive timely the necessary information with adequate level of quality and usability. The UTM tool supports the conduct of simultaneous missions planned in scenario 4. The infrastructure and the distribution of data matches end-user's needs. The architecture set up and the data transmitted support appropriately relevant stakeholders in performing their tasks.
OBJ-VLD-POD-003 Safety	CRT-POD-003-001 CRT-POD-003-002 CRT-POD-003-003 CRT-POD-003-004	Fully covered	UTM systems increases safety levels by provision of appropriate data from pre-flight to post-flight phases. Demonstrate limitation of air risks in VLL airspace by U-space services. Demonstrate limitation of ground risks by U-space services. Demonstrate capability of U-space services to decrease risk of penetrating no-fly zones.	Awareness is increased for airspace users, strategic deconfliction and conformance monitoring are ensured. Drone pilots and other airspace users (GA) get relevant information for identifying, locating and avoiding other air traffics. Drone pilots get relevant information to identify, locate and avoid ground hazards. UTM tool increases drone pilots' capability to identify & avoid no-fly zones, during pre-

Demonstration Objective	Demonstration Success criteria	Coverage and comments on the coverage of Demonstration objectives	Demonstration Exercise Objectives	Demonstration Exercise Success criteria
				flight and flight phases.
OBJ-VLD-POD-004 Security	CRT-POD-004-001 CRT-POD-004-002	Not covered	Demonstrate resilience of U-space services alignment with business & safety requirements. Demonstrate U-space services preventing abuse of drone operations for malignant purposes.	None
OBJ-VLD-POD-005 Standards and regulation	CRT-POD-005-001 CRT-POD-005-002	Partly covered	Demonstrate that impact of U-space services on operational or technical standards is appropriately documented. Demonstrate the level of information regarding possible impact of U-space services on regulations.	For all scenarios, all along the demonstration, evaluate the quality of relevant information provided by Unifly and provides recommendations
OBJ-VLD-POD-006 initial benefits assessment	CRT-POD-006-001 CRT-POD-006-002	Fully covered	Demonstrate that U-space services improve cost effectiveness of flight preparation. Demonstrate that the U-space services enhance optimisation of airspace by simultaneous flights.	Using the U-Space services reduces time, efforts, and costs for the operator. The system supports strategic deconfliction before and during flight time, and visualisation of other flights and obstacles in real time.

Table 1 - Demonstration Objectives

A.1.3 Exercise Operational scenarios

The airspace that was used during the demonstration covered the VLL part encompassing airspace class G, traffic information zone (EKOD TIZ), rural, urban areas (Odense city) and VLL airspace. The area used corresponds essentially to the dedicated airspace already attached to the UAS test Centre in Odense.

Due to the establishment of a drone test centre at Odense H.C. Andersen Airport (EKOD) three temporary restricted areas have been established. The Temporary Restricted Areas used for PODIUM was EK R OD1. as follows :

Temporary restricted area "EK R OD1":

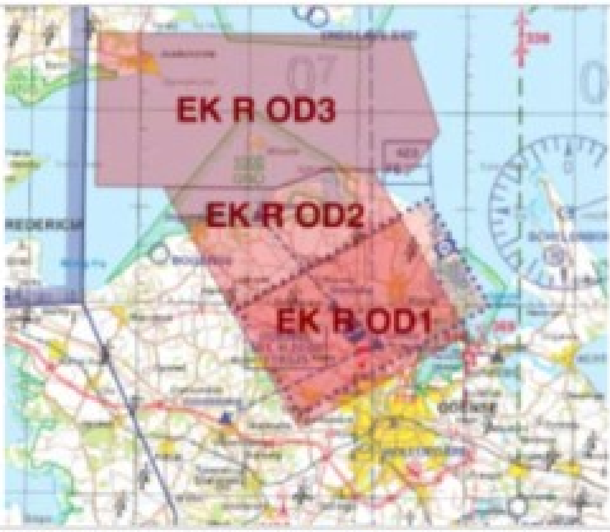
- Vertical limits: GND - 3500 FT MSL;
- Activity period: Will be published by NOTAM;
- No traffic permitted in the area while drone activities are performed within the area. Information about actual drone activity can be obtained from Odense AFIS or Copenhagen ACC.
- BVLOS

Note: The airport will not be closed while the area is published active as H.C. Andersen Airport has made arrangements to ensure that drone activities will be limited to facilitate traffic to and from the airport. However, it is important to note that no traffic is allowed to enter the area until it is reported from Odense AFIS / Copenhagen ACC that no drone activity is in progress within the area. To and from H.C. Andersen Airport IFR-flights can expect less than 5 minutes' delay and VFR-flights less than 10 minutes' delay.

Aeronautical chart – ICAO ANC Denmark

Drone web display

Urban area: 10 km from airport to city center



Dedicated airspace for long distance, long endurance and high altitude BVLOS operations.

Figure 2 Denmark/Odense aeronautical charts

Description	**EXE-VLD-ODE-001**: Multi-mission scenarios operated in VLL, urban and in class G airspace from ground level up to 3500ft. Will reflect the conduct of drone operations as VLOS, BVLOS and VFR operations. Involvement of the general aviation community as airspace users to create in reserved airspace the conditions of normal operations, with de-conflictions ensured by geographic, time and airspace block segregation. The scenarios pursued the investigation of the conduction of flights that could be said to be conducted in the near future. E.g. Long-haul large drones, drones and general aviation and BVLOS flights for inspection purposes with small to medium sized drones. The scenario included some automated flights, which resembled the use of autonomously operated vehicles. E.g. autonomous fence inspection. However due to rules and regulations, all flights were conducted with a drone pilot. **Scenario 1**: Demonstrate VLOS and BVLOS flights from an automated flight plan. VLOS flights consists of ordinary inspection flights being conducted in a fashion, which is commonplace for multirotor and fixed wing respectively. BVLOS flights consist of a simulated field inspection within EK R OD1 northwest of the runway in its own segregated area defined through the UTM system. **Scenario 2**: Demonstration of the UTM system in an automated simulated parcel delivery flight making use of the UTM systems path planning tool. Other drones fly in accordance with the area

	definition planning tool and will adhere to this. Possible interference and violations of the drones' flight areas will be carried out to test the warning indicators in the sentry end and the drone pilots end of the system. **Scenario 3**: Demonstrate the use of the UTM system in connection with inspection tasks within the airport. Missions were conducted VLOS along a section of the airport fence. With the experiences gathered from scenario 2 the flights were automatically flown. Simultaneously 2 smaller semi-professional drones roamed around on the airports UAS test field to simulate an ordinary day in HCA Airport with both ordinary flight traffic and drone tests being conducted. **Scenario 4**: Demonstration the UTM system in operations nearing mission types that are similar or close to similar to operations that are conducted in general on a daily basis today through e.g. different types of inspection missions by various private actors. These types of missions are common among small to medium sized companies who use UAV's as a tool. Thus, the use of UTM in this type of scenario may uncover to what extent a UTM solution ensures coordination and deconfliction between various types of drones in a specific area. Furthermore, this scenario was divided in two with the purpose of demonstrating simultaneous flights with a general aviation aircraft and a single drone. Partly to monitor how they are visible in the UTM system, partly to demonstrate what it would mean to bigger cargo drones in the future to be fitted with the proposed tracker technology. **Scenario 5**: Demonstrate how to use the UTM system in emergency situations. Simulate different kinds of emergency scenarios with multiple drones and emergency services. The demonstration will take place in HCA Airport.
Demonstration Technique	Live Trial
KPA/TA Addressed	Flight efficiency, Capacity, Safety, Cost effectiveness, Security, Human performance
Number of flights	23 out of the proposed 45 flights were conducted, as qualitative data gathering was weighed more than the amount of flights. BVLOS (maximum 10 km range)
Start Date	25/04/2019 due to weather and delay in approval gatherings
End Date	23/05/2019 Last flight with the rearranged scenario 3 being conducted as the last scenario. The demonstration was postponed

	due to bad weather.
Demonstration Coordinator	INAS
Demonstration Platform	U-space service (Smartphone application, Desktop application, U-space Service Provider application, Open API solution); Trackers (GSM) ; Drones (Fixed-wing, Multi-rotor)
Demonstration Location	Hans Christian Andersen Airport, Odense, Denmark
Status	Completed

Table 2: Demonstration Odense Exercise layout

A.1.4 Exercise Assumptions

Identifier	Title	Description
POD-A1	BVLOS procedures	BVLOS procedures are in place with the aid of SDU's BVLOS approval as the Integra approval did not come in a timely manner
POD-A2	BVLOS approvals	BVLOS operations are approved by the CAA
POD-A3	Tracker compatibility with drone	DroneID tracker (and potentially uAvionixs) are compatible with the various drones, and in particular the smallest one
POD-A4	Tracker compatibility with U-space	The UTM hardware is suitable to the drone (weight, dimension, etc.)
POD-A5	Airspace users	The UTM hardware can be installed in manned aircraft
POD-A6	Drone flight route design	Airspace users are fully involved to ensure manned/unmanned cooperation tests
POD-A7	Airport procedures	Airport procedures are rightly adapted to the conducted scenarios and communication is in place to operate in ordinary day-to-day activities in the airport
POD-A8	Manned aircraft	General aviation are fully involved in one demonstration to ensure manned/unmanned cooperation tests. Full involvement of outside aircrafts were not possible.
POD-A9	Baseline U-space documents	All the necessary documentation is delivered during WP 2.2
POD-A10	Drone pilot and operator availability	Drone pilots are available during the demonstration period
POD-A11	U-space platform available	The U-Space platform is delivered sufficiently in advance (i.e. beginning WP 4.2) to facilitate testing
POD-A12	ATC available	The AFIS is participating actively to the preparation and conduct of the demonstrations but could not find the resources to assist as supervisors while operating the tower
POD-A13 (New)	DroneID Tracker availability	DroneID are available in sufficient number to equip participants, including GA aircraft

POD-A14 (New)	Tracker compatibility with general aviation	The DroneID tracker used (or uAvionics if GA aircraft not equipped with ADSB) can be mounted on GA aircraft, or helicopters
POD-A15 (New)	Availability of the large fixed wing drone	The large fixed wing system specifically developed for Podium (MUGIN) is approved by CAA. No special approvals were needed as the platform remained within the threshold of a Category 2 drone in accordance with Danish legislation.
POD-A16 (New)	Delivery route design	The routes and procedures for flying delivery operations are appropriately designed. As the delivery drone did not go fully autonomous, no authorities needed to grant any special approvals (overflight, distance form building, etc.)
POD-A17 (New)	Drone autonomy	CAA would not approve autonomous flights. Thus, the demonstrations only came as close as possible by being flown automatically. A drone pilot could intervene at all times.

Table 3: Demonstration Exercise Assumptions

A.2 Deviation from the planned activities

Despite having concluded all scenarios satisfyingly within the given timeframe, the demonstrations would see some practical deviations from what was initially planned. This is primarily due to visions for the projects meeting the harsh realities of how rules and regulations are constructed for a general environment of drones and unmanned vehicles without any overall safety and security systems implemented as of yet.

Furthermore, some delays and deviations from the planned activities happened because of some outside factors, which could not have been foreseen. All deviations and delays are described below:

- Scenario 3 had to be postponed due to bad weather as winds were too strong. Overall the winds were 9 m/s, but with gusts at 15 m/s it was assessed that it was too risky conducting the demonstration. Thus, the demonstration was postponed until 23 May as the last of the demonstration flights. Otherwise, the weather treated us kindly and we only had minor delays due to light showers, which only set us back an hour at most.

- Due to challenges regarding getting necessary approvals for BVLOS flights, the amount of BVLOS and EVLOS was reduced to only one flight. Integra did not get their approval in time, which meant that SDU who already had approvals for their Sky-Watch Cumulus V1 was used instead. The reason for not flying EVLOS as well is that it is still regarded as a BVLOS flight, thus making it equally challenging getting the approval. Even though these challenges occurred, the work around it meant that the quality of the flight was maintained. Instead of EVLOS, a section of the airport fence was flown instead and gave adequate information back to the UTM system, to make assumptions of the usability. By having help from SDU, an additional stakeholder came in and gave their assumptions on the system in relations to how they conduct research flights.

- In the project scope, it was stated that a total amount of 45 flights were to be conducted during the demonstration days. The total amount ended up being 23 as the former amount turned out to be hard to comply with as training, flight planning, filling out surveys and discussions about the system took longer than expected.. In practise, Integra considers that the experience gained from the 23 flights, together with the flight planning and familiarisation activities, was more than sufficient to support the findings of this report. Moreover, Integra also gained significant experience with the system during the Mock-up activity held at HCA on January 23 and 24 2019 [4].

- One of the reasons for the decreased amount of flights was also because of resetting the scenarios for each flight, which meant that the drone pilot needed to fill out information, plan the mission and get permission to fly before each flight. It is a lot of administrative work, which took longer than expected. However, this actually meant that the system was fully tested by an average of three drone pilots and one supervisor before each flight. Thus, we extensively used the system approximately 90 times throughout the test runs. This has given an excess amount of data on the UTM system and the Drone-ID's, which are the primary test subjects, whereas the scenarios to some extent are secondary.

- As Hans Christian Andersen Airport is a small commercial airport, the demonstrations had to give way for the occasional landing and taking off of regular air traffic. This resulted in some down time, as conventional air traffic got booked in our slot times, however the procedures surrounding these types of incidents got tested even though waiting time can be frustrating. The waiting time was spent instead on discussions on the system, the mission etc.

- ARTAS challenges: In the initial planning phase of the project it was difficult to get clear answers about which specific Asterix categories that was going to be used by each different drone position sensors. At the time it was also unknown which solution & contents that EU/EASA would prescribe for the drones Remote Id. It was clear that there is a very different perception about where & how tracking for UTM & ATM should take place.

  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.

  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.

Due to the delays it was necessary to revert to already proven methods using an offline replay of the traffic could be established via a freestanding pc. It was however not possible to find an air situation of relevance to replay and the practical inclusion of the data connection to the UTM (cloud) was deemed unsurmountable.

A.3 Exercise Results

A.3.1 Summary of Exercise Results

This section provides a summary of the extent to which the demonstration objectives and success criteria have been satisfied in the actual demonstrations.

Demonstration Objective (as in section 5 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> It was speculated who the supervisor in a real-life situation would be and in which business construction he would be located. This was discussed throughout the demonstrations, but in the end was clarified by the statement that "the supervisor is in charge (of the airspace)", without speculating where he would be located in any given corporate system Pilots were delighted about the systems usability in terms of flight planning. If all approvals could go through the UTM system, it would be easy to perform even special tasks as the system both can work automatically and via special permits. There were some speculations about usability of the way you file for special approvals. It was harder to find with various sub-menus than just filing for automatic approvals. Supervisor observed some lack of information regarding missions and the ability to allow people to fly in areas where there might already be operations. No procedures for phraseology or communication was put in place beforehand. It had/has to be invented.	POK
		<u>Flight-execution</u> It is not possible to communicate through the system while in flight between Pilot and supervisor. Drone pilots could not really use the mobile app to do anything. It could be replaced by a fly now/land button. Radio communication between AFIS and Supervisor was formalized through normal radio procedures in Hans Christian Andersen Airport. Communication between supervisor and drone pilot/observer used same procedure.	POK

Demonstration Objective (as in section 5 of Demo Plan)	Demonstration Success criteria (as in section 5 of Demo Plan)	Exercise results	Demonstration objective status (OK, NOK, POK (Partially OK))
		Line of communication was AFIS -> Supervisor -> Drone Pilot/Observer Supervisor had main decision-making right towards the drone pilots. Supervisor was satisfied with flight mode and the ability to see the drones' whereabouts at all times.	
OBJ-VLD-POD-002 Technical feasibility	CRT-POD-002-001 CRT-POD-002-002 CRT-POD-002-003 CRT-POD-002-004	<u>Pre-flight</u> The system did not notify the supervisor when new submissions were added from pilots. Unique auto generated mission-ID's could as well be a thing for development as more submissions at once made it hard to distinguish one from the other. Mistakes could be made It was possible to grant permission for flights that could potentially lead to mid-air collisions as supervisor could not compare flight areas when new submissions came in. Potential for human errors. System did not inform pilots of risks when planning on top of other planned flight areas.	NOK
		<u>Flight-execution</u> 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 did not give much information. Furthermore, it was not integrated into the drone software, which thus required an observer to operate the mobile end of the system. If the system is only meant for stating taking by opening the app and pocketing it when flying, the drone pilot could be on his own. However, if the system should be used for more than reporting, the drone pilot will at the present state not be able to use the system single-handedly. The tablet version of the system did not hold information about the drones or other drones' position. Thus, there is no situational awareness. When stating take-off in the handheld UTM system, the mission appears as a new unnamed flight but with the same desired flight time as the one planned for. Reports from Unifly state that this should not be the case. The system should have the information provided if the drone pilot went into the	POK

Demonstration Objective (as in section 5 of Demo Plan)	Demonstration Success criteria (as in section 5 of Demo Plan)	Exercise results	Demonstration objective status (OK, NOK, POK (Partially OK))
		scheduled flight beforehand. However, it did not, and the system showed the flights as a similar operation with the same credentials but as 'unnamed'. The fact that you had to be careful to open the operation beforehand to use it for reporting presented some frustrations.	
OBJ-VLD-POD-003 Safety	CRT-POD-003-001 CRT-POD-003-002 CRT-POD-003-003 CRT-POD-003-004	<u>Pre-flight</u> The pilots were aware of restricted areas and no-fly zones and could also see temporary no-fly zones. The supervisor was aware of missions but could not see overlapping flights as only the mission being walked through would show on a picture and in writing when granting permission. Other potential overlapping missions would not show.	POK
		<u>Flight-execution</u> The supervisor end of the system would be the one that could avoid collisions. However, it would not be possible to communicate through the system to the drone pilot when in flight. Via radio it is possible to warn. Information could be delayed if it has to go through the supervisor. The drone pilot could not see the presence of himself or other drones in the area. Drone pilots are left in the dark. 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. Situational awareness is needed.	POK

Demonstration Objective (as in section 5 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-004 Security	CRT-POD-004-001 CRT-POD-004-002	Dedicated Orange Network meant that data was transmitted on a secure and dedicated line. A TDC sim card (Danish network provider) was tried out for the BVLOS flight, and the UTM system handled it well. This means that the system does not care about different secure line providers. DroneID trackers were very accurate with transmitting altitude and position. However, fixed wing drones showed some problems with shadowing in some manoeuvres, which meant that the position in these circumstances would be several meters off. All UTM user accounts are protected behind a log-on image and cannot be accessed without credentials and password.	POK
OBJ-VLD-POD-005 System performance assessment	CRT-POD-005-001 CRT-POD-005-002	<u>Pre-flight</u> The Unifly system works well as a planning tool. Ideally speaking all planning and preparation could be done easily and flexibly from there. The only issue would be having a central approval authority to deal with the various special permits. The system, however, cannot function without a supervisor, and the supervisors role should be defined in-depth by an authority. A decentral operator supervisors would not make sense in a Danish environment where the supervisor would have to be The Danish CAA and the Police, e.g. airport towers to grant full permission. If the task of the supervisor was to be decentralised, it would only be useful in an area fully controlled by that operating supervisor. E.g. in restriction zones and privately owned areas. System only works in situations where you need to plan ahead. Emergency services need to activate areas instantaneously and cannot use the planning tool for much.	POK
		<u>Flight-execution</u> All in all the UTM system works well in the supervisor end of the system. The operator end still needs some improvements to live up to the U-space level 3. Situational awareness for the drone pilot is a	POK

Demonstration Objective (as in section 5 of Demo Plan)	Demonstration Success criteria (as in section 5 of Demo Plan)	Exercise results	Demonstration objective status (OK, NOK, POK (Partially OK))
		pivotal issue when it comes to flexible use of airspace. The integration of systems was not demonstrated, as the ARTAS feed was not available to be fed into the UTM system. However, it seems that the Unifly system will handle all data given to it as demonstrated through the use of trackers with different sim cards. The UTM system needs additional feeds from an ADS-B or other if it should support high flying drones. A GSM based tracker such as the Drone-ID can only go up to a certain height above the phone masts before the signal is lost. During the trials, this was 700 meters.	
OBJ-VLD-POD-006 Standards and regulation	CRT-POD-006-001	Pre-flight With the UTM system you only need one flight planning app. Flight planning, approvals and supervision is built into the same system, which makes it easier for all stakeholders to handle before flying	OK
		Flight-execution There are no standardised messages between supervisor and drone pilot. E.g. You cannot send a “Land now” to the pilot or “give way”. All communication while in flight has to be done via radio. There are no rules and regulations put in place that grants the use of UTM systems as a mitigating factor, thus the two works separately. Thus, having to file for a BVLOS approval is not made easier just because of active tracking and UTM Systems. All traffic must be included into the system, if proper flight planning should take place through the UTM system. You are only working in silos at the moment. Incoming IFR and VFR traffic is not displayed.	POK
OBJ-VLD-POD-007 initial benefits	CRT-POD-007-001 CRT-POD-007-	Pre-flight All planning is made easier. Approvals and all communication can take place through the system	POK

Demonstration Objective (as in section 5 of Demo Plan)	Demonstration Success criteria (as in section 5 of Demo Plan)	Exercise results	Demonstration objective status (OK, NOK, POK (Partially OK))
assessment	002 CRT-POD-007-003	The system still needs some work on the usability scale, but all planning can be done without much prior training. In-app notification would be a strong selling point. You are not notified of new messages or changes to any applications. E.g. when applying for an approval you would have to stay in the window for approvals to see if the status changed. You would not get a pop-up message stating that you have a new message or that there have been changes to an ongoing application – this is applicable to both the supervisor and the pilot. If the supervisor should have multiple permission requests, he would have a hard time keeping track on any additional submissions or requests. Furthermore, it is not possible to see what is required, if the supervisor needs additional information or documents. This could make e.g. SORA submissions difficult We were not able to get automatic permissions as the system would not let us when being in an airport. Every submission had to be manually approved. The proposal states: “Different levels of automated flight permissions will be demonstrated” (Proposal number: 783230, 2017: 7).You do not have all information at hand if you want to increase the amount of drone flights, as you can only see one planned flight at a time. You do not have any deconfliction aides when granting permission as a supervisor.	
		<u>Flight-execution</u> Without integration into drone software, there is no cost-effective by using the UTM system in flight. You do not get any information about your surroundings, you do not know where you are, and other drones are not monitored through the pilot end of the system. You would need an extra person to keep an eye out for the UTM system, while the drone pilot steers the drone. One person simply cannot operate two systems. At the moment, the mobile app could be replaced with a big red fly now/land now button with connection to the planned flight at hand, which would work just as good as the app. The point is that the app gives no added value to the pilot in the field when operating the drone, and developers might	POK

Demonstration Objective (as in section 5 of Demo Plan)	Demonstration Success criteria (as in section 5 of Demo Plan)	Exercise results	Demonstration objective status (OK, NOK, POK (Partially OK))
		determine if the UTM system on a hand-held devise should be a situational awareness tool or a reporting tool. If being the latter, the system is too complicated with too much information provided when the pilot then only would need: 1: An option to choose any of a number of scheduled flights and 2: an indication for taking off and landing, If the former: Situational awareness is key and integration with drone software would make it useful. The Supervisor end is the only thing working properly thanks to the flight view function. However, you cannot use the system for communication purposes while in flight.	

Table 4 – Summary of exercise results

A.3.2 Analysis of Exercise Results per objective

The following is a compilation of both qualitative and quantitative results gathered during the demonstration runs in Odense, Denmark. The tests ran across 5 demonstration scenarios, which prompted the participants to submit their experiences with the system. Firstly, by filling out a questionnaire after each flight, secondly by discussing their overall opinions after the entire demonstration run, which was put into a review document for the highlights of the discussions. Furthermore, a post demo questionnaire and a System Usability Scale (SUS) questionnaire was filled out

Throughout the demonstration flights, a total of ten pilots and eight observers participated. They filled out the questionnaires together as “Flight crew”. Furthermore, a total of 5 supervisors participated and filled out their separate type of questionnaires.

1. OBJ-VLD-POD-001 Operational feasibility and acceptability

The following graph depicts the answers of the post demo questionnaire filled by both the flight crew and the supervisor after the entire demonstration exercise.

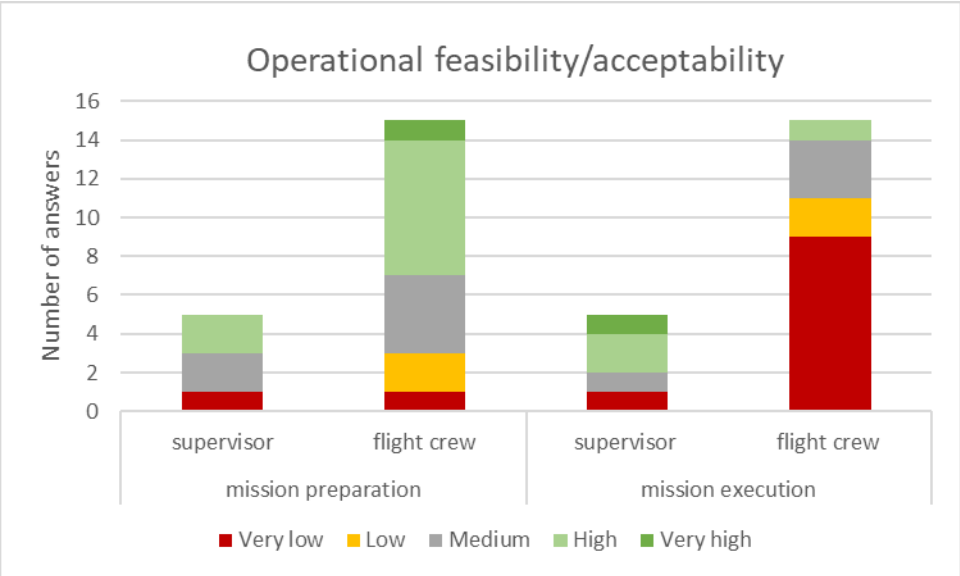


Figure 3 post demo questionnaire: operational feasibility and acceptability of UTM system

The answers indicate that the UTM system and the U space services were acceptable for the flight crew and the supervisor in the mission preparation phase, however that was not the case for the mission execution phase especially for the flight crew.

After each flight the pilots, observers and supervisors were asked to rate the impact of the UTM system on their success of mission / Supervisor task, their workload their situational awareness and the reliability of data.

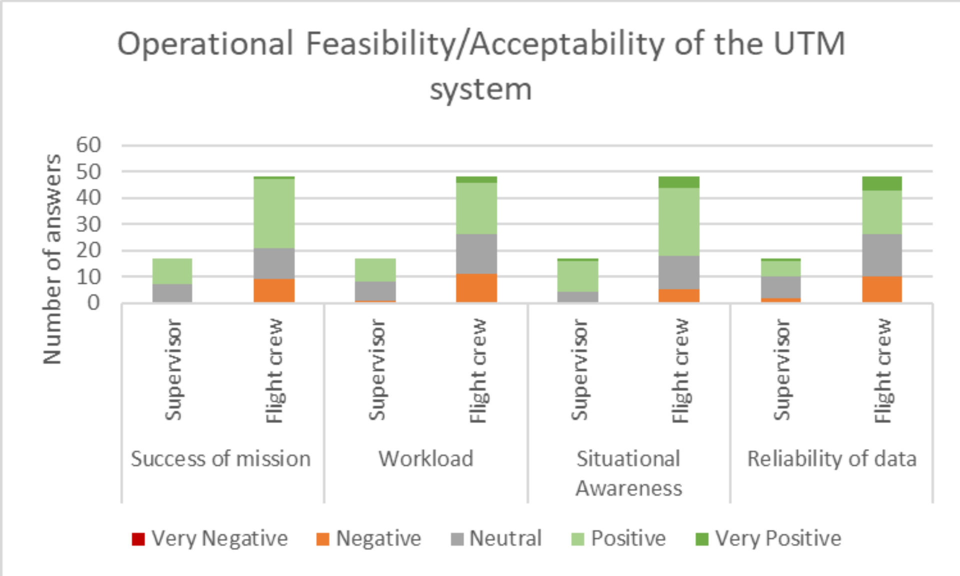


Figure 4 post demo questionnaire: impact of UTM system

The results indicate that the Supervisor rated all categories positive while the flight crew rated it more negative. In the debriefings, the answer was explained by the fact that the drone pilot and observer were missing live data. They could not see their own drone via the UTM system nor other planned and actual flights and zones. While the Supervisor was experiencing the system positively, especially the Sentry system gave the supervisor a good situational awareness and functioned well as a planning tool. Furthermore, the online processing of approvals also seemed very flexible.

The post mission phase was not conducted, as the UTM system did not allow for much post mission evaluation to be done. It could be speculated whether a small program could be run if you have a tab indicating that the mission has ended. With doing so, the system could run through a checklist of what to remember. E.g. reporting back to supervisors, AFIS, ATC etc., rigging down the drone and all related things.

In the post demo questionnaire, the actors were asked if the roles and responsibilities are clear and acceptable to them.

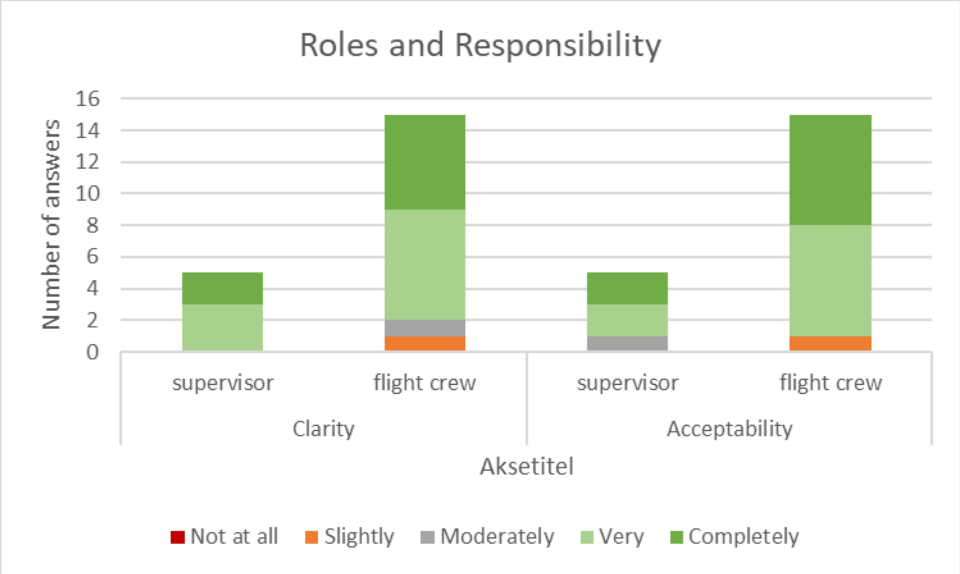


Figure 5 Roles and Responsibilities

For the supervisor the roles and responsibilities were entirely clear and acceptable, while for the flight crew that was not the case. This is to be annotated by the role of the observer and his/her tasks. It was clear that the observer was communicating with the supervisor and the person in charge of the communication to the tower, but the observer was not able to see their own drone nor other drones nor the no fly zones on the system. Therefore, the role and responsibilities of the observer were quite limited.

Pre-flight services

Operator reaction:

As indicated above, all seemed confident in using the system. Training was done fairly quickly, and the system could be operated easily by all participants. In terms of defining the area, the time slot and how to submit applications, all was done with ease. As can be seen from the survey answers above, the main part of the participants answered positively about doing flight preparations. There seemed to be some negative answers, which can only be attributed to the fact that the surveys were done extensively .

In discussions afterwards, a number of pilots and observers argued that it did not matter to do the flight preparations in the system, if it would not pay off for the pilots in mission execution mode. Here, they argued that it would only be an annoyance as they did not have any situational awareness and only to some extent could see their flight area. No communication between supervisor and pilot was possible through the system, which was tested during a number of runs, where the supervisor rescinded the permissions, which did not communicate to the hand-held devices.

There were some discussions about how drone missions would be affordable if another person should be brought along to operate the UTM system in the field (i.e. observer in the exercise), and why the system could not share data with the drones' flight planning and execution software. As it stands now, the drone pilots, thus, must do two flight preparation phases. One for the UTM system, one for the drone.

All in all, the hand-held device gave quite a large amount of frustrations, as it did not provide any apparent operational value to the flights. In terms of the discussion regarding the take-off and landing time for documentation, the pilots primarily used the software of the drones, but this would be the argument for having the system. Then again, it would not add anything to the drone pilot while operating the drone. The pilot had to transmit information through the system but could not get anything in return while in flight. One of the most notable frustrations came about when it came to the fact that you had to do a very specific set of tasks to access the planned operation. You could not exceed the start of your mission. If so, the mission would not show up in your scheduled flights anymore, making it impossible to identify your flight. A number of these incident happened during the demonstrations, and the pilots were only prompted to report that they took off and landed. This in turn showed up as an unnamed flight in the supervisor-end of the system. But that is a discussion for the flight execution mode, which in the survey responses reflected the frustrations.

In terms of the scenario with the participation of the emergency services, the stakeholders stated that a system for flight planning would not be suitable for their quick deployments. As they primarily fly within minutes, they do not have the time to fill out the flight plan or apply for special permissions. There is no quick planning mode for emergency services, which makes it difficult to close off any area. Instead it was speculated, if the emergency services should only use the supervisor entry for all their planning purposes.

Supervisor/ATCO reaction

The supervisor end of the system worked well in communication with the planning of missions. When drone pilots submitted their requests, the supervisor would see it instantaneously in the request section of the Sentry mode. The supervisor could see the planned route or area, possible comments and requests and grant permission. The instant the supervisor granted permission to fly, it was shown on the drone pilots screen.

However, the supervisor reported back that it was not possible to see the exact location of the planned flight path or route, at the image of the planned flight was shown in close up and with only map drawings. Simultaneously, you could not see other planned flights in or near the area applied for by the given drone pilot. Thus, it would be a gamble or good memory for the supervisor to estimate the possibility for the drone pilot to conduct the flight. This came to expression, particularly in the scenarios with the package delivery, where more than one flight path overlapped the flight path of the delivery drone.

Flight execution services

Operator reaction

As stated above, the main part of negative reactions from the operators came in the process of flight execution. The hand-held device for monitoring the flight should benefit the operator in the field in terms of being easily accessible, show situational awareness and ease communication between supervisor and operator. The hand-held version of the system did none of those things, which meant that the hand-held devise easily could be omitted. The only useful thing to do with the app was reporting if the pilot flew or not. Even in this situation the flights only came in as unnamed but with the same credentials as the planned one, which gave some confusion at the supervisor.

The emergency services planned for their flights as well, but could not see a bigger meaning, as they would not be using it. They don't have the time to do it, and they could not wait for a specific slot time as they only fly in case of emergency.

The negative comments and feedback in the post-flight surveys reflect the above mentioned challenges as most pilots and observers were generally negative towards the usefulness of the flight execution software of the UTM system. Their main recommendation was that taking off and landing would be automatically conveyed to the supervisor. Furthermore, they argued for an integration of the system into the different drone software. This would also turn out to be more cost effective, as the system thus would save the need for an observer to operate the UTM system in itself. In terms of situational awareness, the whereabouts of one's own drone would at least show up, if the systems were integrated.

Supervisor/ATCO reaction

It is not possible to communicate through the system while in flight between Pilot and supervisor. During the tests, communication had to be done via ordinary radio link.

Radio communication between AFIS and Supervisor was formalized through normal radio procedures in Hans Christian Andersen Airport. Communication between supervisor and drone pilot used same procedure. Line of communication was AFIS -> Supervisor -> Drone Pilot. AFIS was invited to participate as supervisor. However, they could not find the time or man-power to either assign a man to participate in the hangar or use the system in the tower, while conducting normal operations.

Supervisor had main decision-making right towards the drone pilots.

Supervisor was satisfied with flight mode and the ability to see the drones' whereabouts at all times. However, the sentry mode would warn the supervisor about possible collisions, but it would not retain the warning, and supervisor would risk missing the warning. Furthermore, you could not click on the warning to centre where the collision would be a risk. In discussions about this particular problem, the supervisor noted that the nature of ordinary drone flights, would warn about the risk of collisions and the next second, there would not be any problem.

Supervisor complained about not having any altitude indications during flight and minor challenges with battery time on the Drone ID's would show after a whole day of flying.

All in all, the supervisor was more positive towards the system, as he had a good overview over the activities. He could not do much through the system, if errors occurred. He could not rescind flight permissions, and when warning about collisions via radio, communication would already be too late.

In the post demo questionnaire, the actors were asked if the tasks and procedures are clear and acceptable to them.

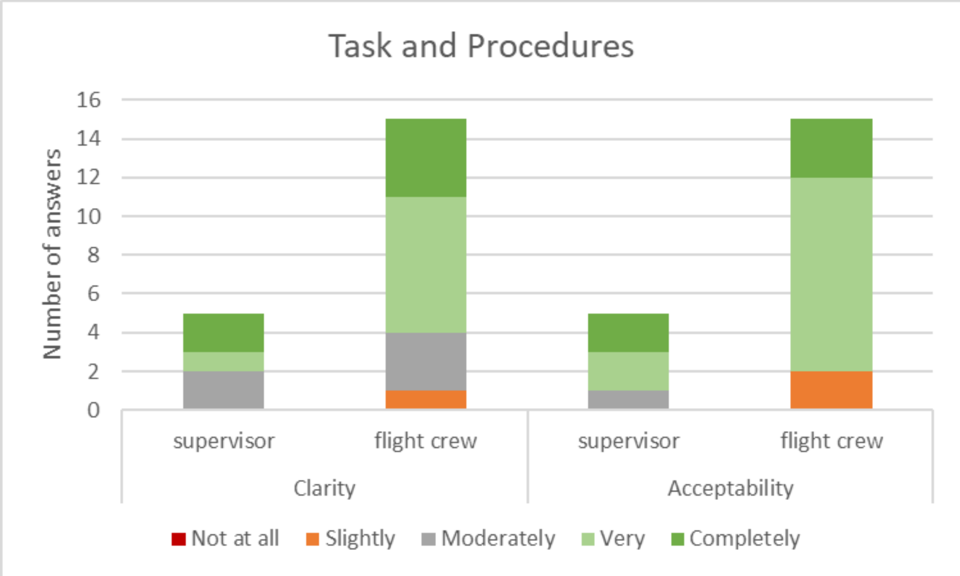


Figure 6 Tasks and Procedures

The answer to the questions on task and procedures is very much in line with the answers given on roles and responsibilities. The tasks were clearer for the supervisor than for the flight crew due to the reasons mentioned above.

2. OBJ-VLD-POD-002 Technical feasibility

In the post demo questionnaire, the actors were asked to rate the timeliness of the information provided by the system. This included rating how they would regard the timeliness of information provided from the supervisor to the pilot and from the trackers to the supervisor and the system.

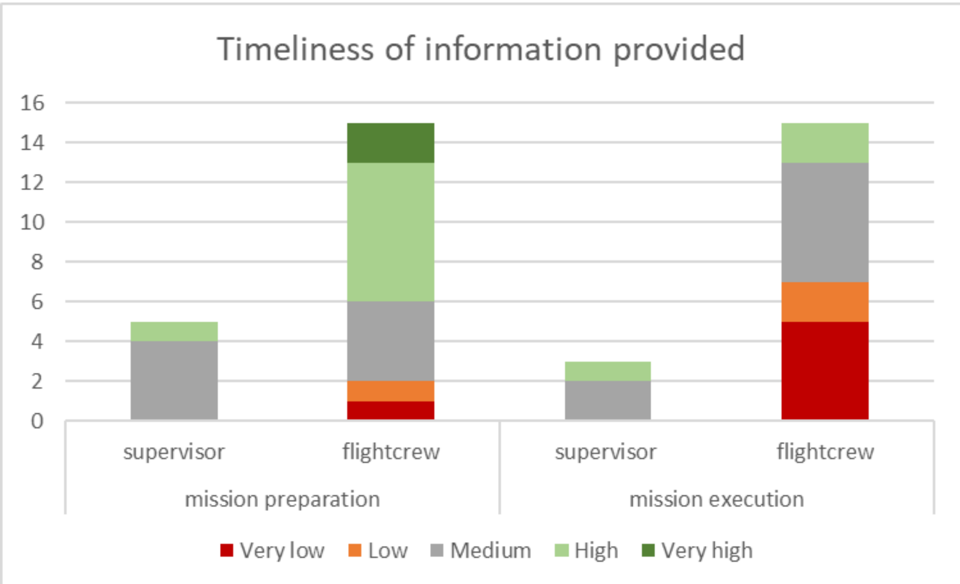


Figure 7 Rating on Timeliness of provided information

The answers of the flight crew were more negative than for the supervisor and especially for the mission execution phase. The answers relate again to the fact that as no other drones were visible on the system and that they would not be warned in time when a drone enters their area. Furthermore, it was explained that the despite the fact that the mission is planned for a certain time there might be a possibility that this time is missed by a few minutes. If this is the case and the planned flight passes the scheduled take-off time, there is no possibility any longer to see the planned flight in the system. Just as stated above, the drone pilots were overall speaking negative towards information provided by the system, as the system did not provide much information in terms of situational awareness or corrective commands from the supervisor. You could say that the drone pilot was left much more in the dark than the supervisor who would get more information from drone trackers. The supervisor also had situational awareness.

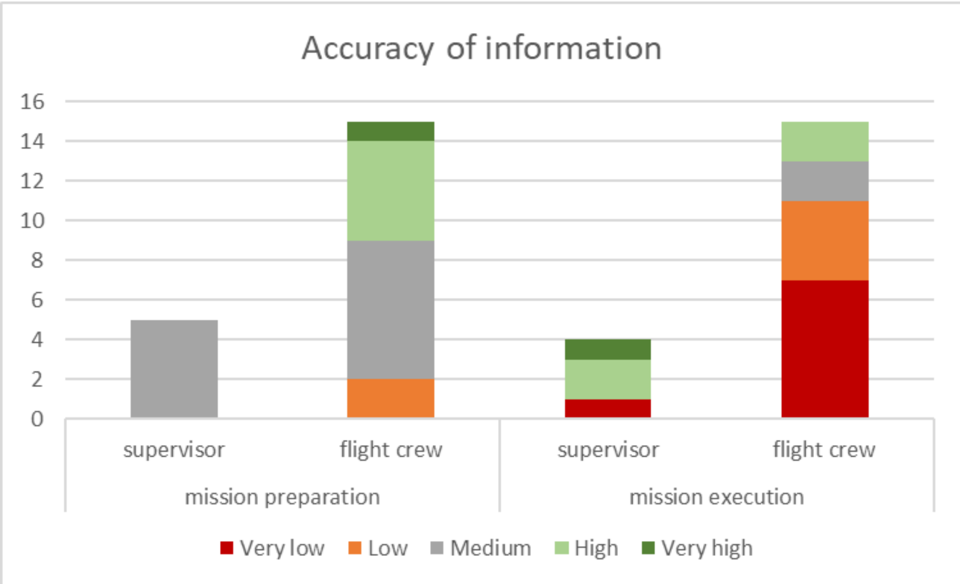


Figure 8 Accuracy of provided information

The answers on the information accuracy related more in general to the availability of information. As mentioned above the flight crew was missing information that they considered important – at least during flight as layers could not be turned on and off when the flight had been started. In the mission execution, certain information such as information about no-fly-zones, other planned zones, weather forecast, altitude of the drone, location of the drone and warnings about unexpected events e.g. if the drone is on a collision path with other drones, should be available.

Drone ID's

Drone trackers easily fit on larger vehicles such as a plane. It also fitted on the rather big MUGIN platform without obstructing any navigational communication. The DroneID weighs very little, and it does not take up too much payload. For the missions on the MUGIN platform and all other drone platforms, every gram count. In this respect, the DroneID is a desired tracking technology, as the developers have actively sought to keep weight down.

Pre-flight

The system did not notify the supervisor when new submissions were added from pilots. Unique auto generated mission-ID's could as well be a thing for development as more submissions at once made it hard to distinguish one from the other. Mistakes could be made

It was possible to grant permission for flights that could potentially lead to mid-air collisions as supervisor could not compare flight areas when new submissions came in. Potential for human errors.

System did not inform pilots of risks when planning on top of other planned flight areas.

Flight-execution

The Supervisor system functioned well. The supervisor was warned about the position of drones and whether they were about to collide.

The tablet and mobile version of the system did not give much information. Furthermore, it was not integrated into the drone software, which thus required an observer to operate the mobile end of the system. If the system is only meant for stating taking off or landing, the drone pilot is on his own.

The tablet version of the system did not hold information about the drones or other drones' position. Thus, there is no situational awareness.

When stating take-off in the handheld UTM system, the mission appears as a new unnamed flight but with the same desired flight time as the one planned for. Reports from Unifly state that this should not be the case. The system should have the information provided if the drone pilot went into the scheduled flight beforehand.

3. OBJ-VLD-POD-003 Safety

In the post demo questionnaire, the actors were asked to rate their situational awareness.

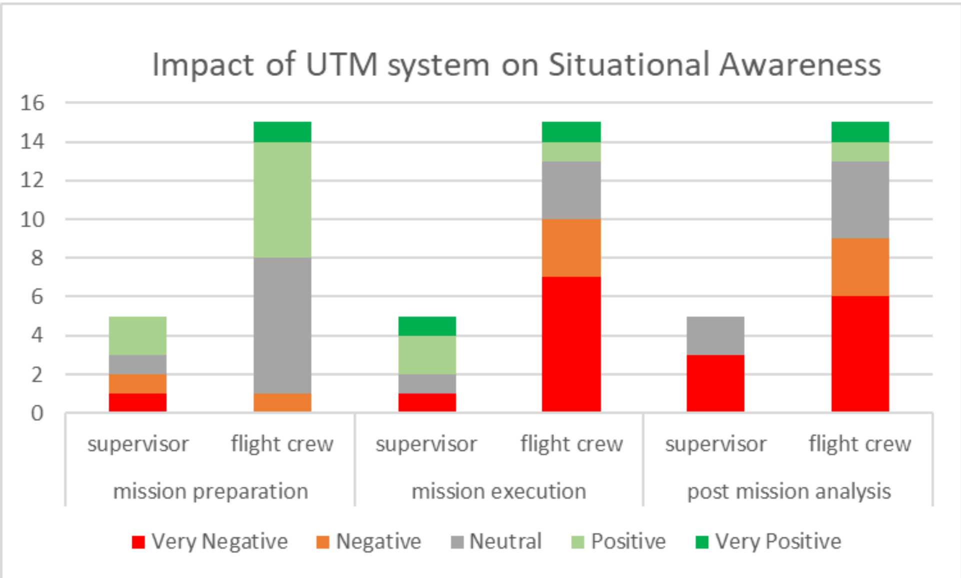


Figure 9 Impact of UTM system on situational awareness

The flight crew gave a negative response on situational awareness, as they were not aware where their own drones were, neither where the other drones were.

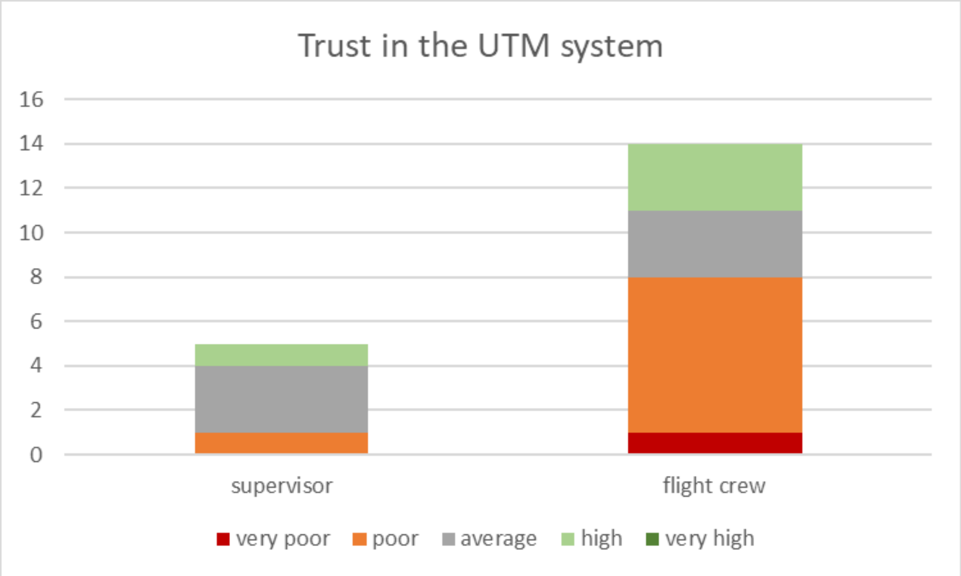


Figure 10 Trust in UTM system

The flight crew rated the trust in the system lower than the supervisor did. This is mainly attributed to the fact that the lack of information about the own drone and other drones in the area gave the impression that information was missing.

The pilots were aware of restricted areas and no-fly zones and could also see temporary no-fly zones.

The supervisor was aware of missions but could not see overlapping flights as only the mission being walked through would show on a picture and in writing when granting permission. Other potential overlapping missions would not show.

Flight-execution

The supervisor end of the system would be the one that could avoid collisions.

However, it would not be possible to communicate through the system to the drone pilot when in flight. Via radio it is possible to warn.

Information could be delayed if it has to go through the supervisor. The drone pilot could not see the presence of himself or other drones in the area. Drone pilots are left in the dark.

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.

Situational awareness is needed.

4. OBJ-VLD-POD-004 Security

Dedicated Orange Network meant that data was transmitted on a secure and dedicated line. A TDC sim card (Danish network provider) was tried out for the BVLOS flight, and the UTM system handled it well. This means that the system does not care about different secure line providers.

DroneID trackers were very accurate with transmitting altitude and position. However, fixed wing drones showed some problems with shadowing in some manoeuvres, which meant that the position in these circumstances would be several meters off.

All UTM user accounts are protected behind a log-on image and cannot be accessed without credentials and password.

5. OBJ-VLD-POD-005 Standards and regulation

In the post demo questionnaire, the actors were asked if the tasks and procedures are clear and acceptable to them.

The answer to the questions on task and procedures is very much in line with the answers given on roles and responsibilities. The tasks were clearer for the supervisor than for the flight crew due to the reasons mentioned above.

Splitting the tasks into preparation tasks and mission execution tasks the following results can be depicted.

Pre-flight

With the UTM system you only need one flight planning app. Flight planning, approvals and supervision is built into the same system, which makes it easier for all stakeholders to handle before flying. All planning should be formalised through central approved systems, though with a connection to the same approving body. In the discussions about the system in one of the

Flight-execution

There are no standardised messages between supervisor and drone pilot. E.g. You cannot send a "Land now" to the pilot or "give way". All communication while in flight has to be done via radio.

There are no rules and regulations put in place that grants the use of UTM systems as a mitigating factor, thus the two works separately. Thus, having to file for a BVLOS approval is not made easier just because of active tracking and UTM Systems. If the system should be recognized as a central system standard, it must be formalised as a system with access to the granting authorities. In Denmark, the role of approvals and information must be done to several different public bodies before flying such as the Danish CAA, NAVIAIR, the local police department and possible airports. A centralisation would thus be necessary so that all approvals would be done from one point and fairly swiftly. This form of centralisation is not yet in place, but could be e.g. by granting this service to the CAA, an ANSP or similar bodies.

All traffic must be included into the system, if proper flight planning should take place through the UTM system. You are only working in silos at the moment, which means that you need more systems than one and a supervisor, an ATCO or AFISO to inform and direct all in-air stakeholders. Incoming IFR and VFR traffic is not displayed.

6. OBJ-VLD-POD-006 initial benefits assessment

The results on the flight execution task depict the following results.

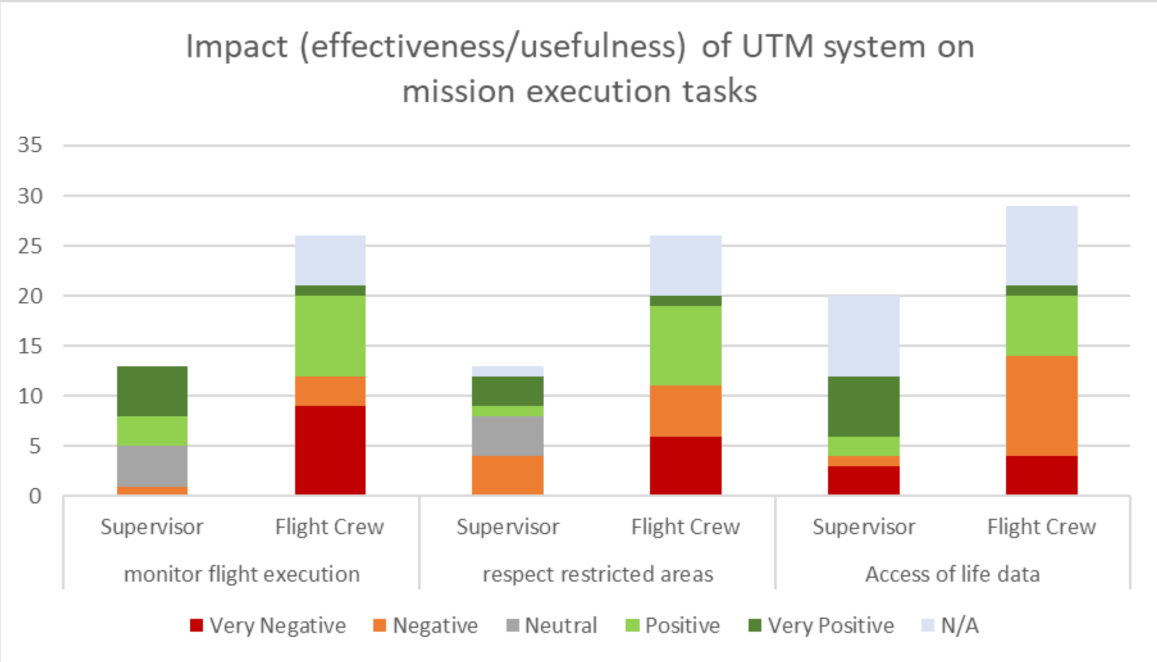


Figure 11 Impact of UTM system on mission execution task

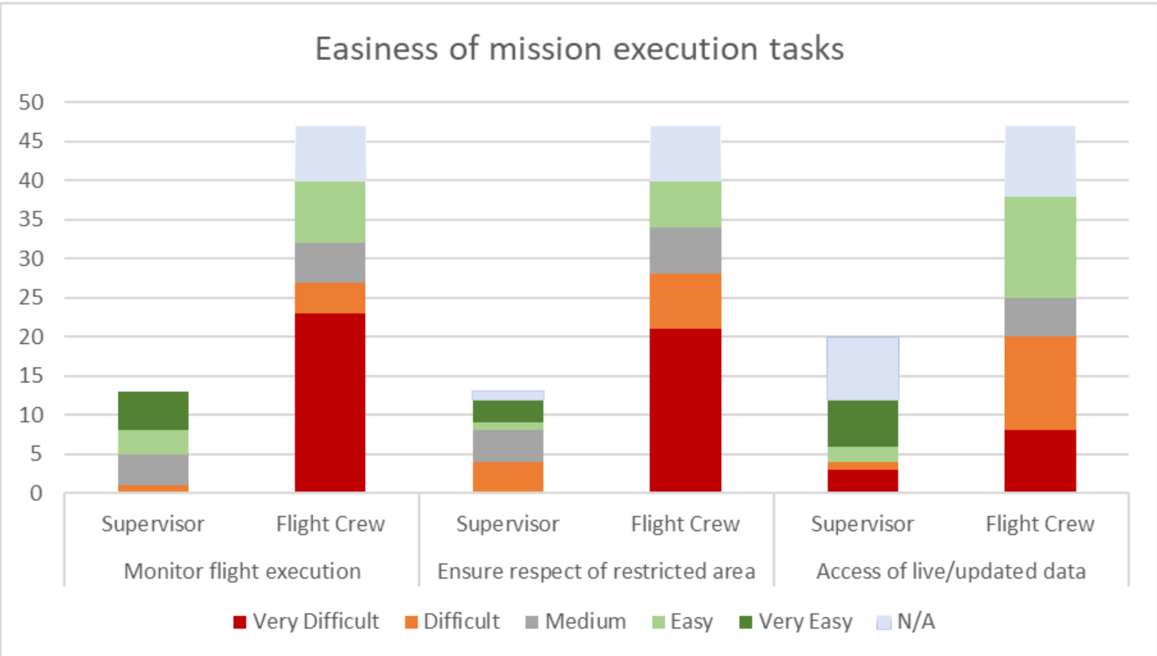


Figure 12 Easiness of mission execution task

While for the Supervisor the answers were balanced, the answers of the flight crew were mainly negative. For the flight crew the main point missing on the UTM system was the current position of the drone and the other drones flying in the area. The flight crew was not aware where the restricted areas were. They had to get this information from the Supervisor via radio. For the Supervisor, it was an issue that NOTAM's, weather data, etc. that were not easily accessible via the system online.

Systems usability scale

The usability of the system was assessed via the System Usability Scale (SUS) and different questions in the post demo and post flight questionnaires.

The System Usability Scale was used in order to identify the ease of use, efficiency and effectiveness of the UTM system. The SUS scores range on a scale from 0 to 100. The higher the score obtained, the higher "ease of use", "efficiency" and "effectiveness" of the tool provided.

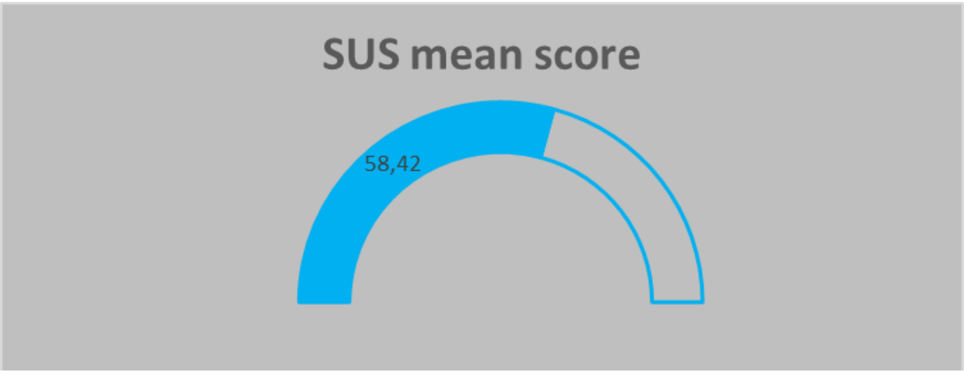


Figure 13 System Usability Scale score

On a scale from 0-100 the system was rated with 58,42. Based on research, a SUS score above a 68 would be considered above average and anything below 68 is below average. In percentages, this result indicates a percentage rank of 58%. The comments were that the functions available are good but there are still a few needed functions missing. These are outlined in the requirements.

On elaborating on the usability scale in the discussion subjects, all participants could agree that there is potential in the system and that much of the functions are well thought of, also for moving in the direction of U1, U2 and U3. However, the execution of the functionalities still needs some development before being completely user-friendly. In the flight planning phase, it is the rearranging of some functions and the addition of notifications of new messages and updates. To notify the users when communicating in the approval process.

It might be necessary to uncover what the hand-held app should be used for. In terms of usability, it is not very useful at present, as it seems that it cannot be used to monitor the flight while in progress and it reports back to the supervisor entry rather poorly. One could speculate that the reporting back could be done automatically with the tracker technology, as it monitors altitude and location at all times. This would in turn make the hand-held app obsolete – unless there was some added situational awareness of one's own drone or others.

A.3.3 Unexpected Behaviours/Results

Tracking information:

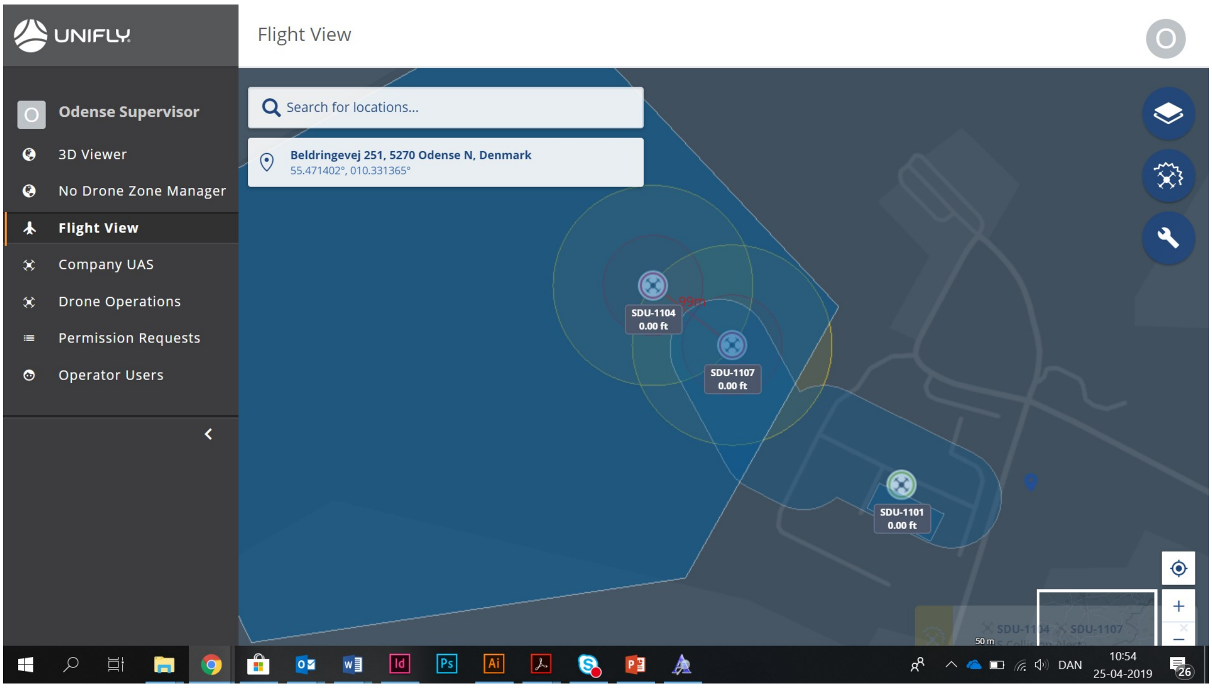


Figure 14 Drone ID tracker not showing altitude while in flight

During the dry-run and into the first two demonstration runs, the information about altitude did not communicate into the UTM system. When talking with the project manager of the SDU Drone-ID's, we learned that altitude information was being transmitted. However, somewhere in the transmission, the information did not convey. Unifly was notified about the problem and worked on the issue so that altitude information did in fact convey with accuracy. In the beginning AMSL. On the fourth run, this was changed to AGL, which made it easier to monitor.

It was discovered that tracking information would disappear if other people used the supervisor entry. If a person logs into the supervisor entry, the last one logging in will be the one who receives tracking information. When logging out again, the information will be transmitted to the former supervisor again. The issue was particularly notable during scenario 1 on 10 May, where the supervisor lost track on all the drones during one of the missions, which prompted the scenario run to end. After consultation with Unifly, all developers were prompted not to use the system. The problem did not reoccur.

Battery power:

Battery power on the drone trackers was told to be limited, and drone pilots were prompted to turn off the Drone-ID between each demonstration run. However, the first day of flying proved to take its toll on the batteries, why the trackers one by one ran out of power at the end of the day. A focus on power conservation for the remaining tests, made the problem disappear – at least for the tests. However, battery power and the placement of the DroneID as an external unit running the risk of being tampered with might be something to consider.

Keeping to one's flight areas

Figure 15 BVLOS scenario and tracking details

It proved to be rather difficult for the drone pilots to keep to their designated flight areas. In the

In the figure above, a couple of issues are highlighted. It can be seen that none of the drones are keeping within their designated flight area, simply because it was difficult for the pilots and observers to see exactly where they were.

A further problem is shown, as the drone with the tracking information SDU-1101 was moved to a different location. An ad-hoc flight area did not show up while in flight, and he would just show up on the map without a flight area, while his originally planned area is shown in the right side of the image. Reports from Unifly state that this should have been the case. However, as the above figure shows, the ad-hoc mission would not show an ad-hoc flight area, although the observer reported that the hand-held app was used to report about the flight.

One last issue relates to the fact that missions could be planned on top of each other. In this particular scenario the MUGIN flight and the BVLOS flight mission plans overlapped, which in reality proved to be no problem as the pilots communicated with each other and discussed their flight paths in the field. However, this is the usual way of flying in Hans Christian Andersen Airport today, giving no added value or arguing for a UTM system. It is evident that the inability for the supervisor to see other planned flights together gives these unfortunate risks of having multiple drone missions in the same planned area without the supervisor knowing to warn the drone pilots that this is the fact and that the drone pilots in turn should be aware.

Emergency services - Special UTM

During scenario 5 on 16 May with the participation of The Greater Copenhagen Fire Department and the Fyns Politi (Police Department of Funen), it was noted that flight planning would be a nuisance to a fast response. When being called out on a special assignment, the emergency service drone pilot would not have time to plan ahead. They stated that a quick deployment application with an automatically generated no fly zone at a given radius from the drones' take-off site would make it more usable for emergency services.

When discussing if it would be better for emergency services to bring the sentry end of the system on-site, the stakeholders responded that it would be an extra task notwithstanding, and that dispatch or the rescue manager would not have the time to plot in a temporary no-fly-zone. Instead it was speculated that the flight radius of the emergency drones could automatically set up a temporary no-drone zone, which would be revoked when the mission was over.

Drone ID's on high altitude vehicles

Calling it an unexpected behaviour or result would be a stretch, as it was expected that taking the DroneID to an altitude above ordinary GSM antenna height would prove to be problematic. Notwithstanding, this was exactly what was done during Scenario 4-2 with the inclusion of General Aviation. The aim of the scenario was initially to monitor how general aviation and drones could co-exist within the same airspace.

However, because of the issue with the ARTAS feed and the plane being equipped only with Mode-S ADS-B, it was agreed that the plane instead should be fitted with a DroneID tracker to see if it could be used on ordinary air traffic, and whether it could be used on drones that go to the same heights as planes in the future.

As expected, the Drone ID's gave up at approximately 700 meters AGL proving that GSM technology for high altitude vehicles have some inexpediencies to be a proper alternative to the more widespread technologies such as ADS-B in some form or another. One could argue that at high-altitude vehicles would be of a size to accommodate conventional tracking and communications technology. It, of course prompts that the UTM system receives information about other trackers than drone trackers, which the Unifly system is capable of doing.

A.3.4 Confidence in Results of the scenarios

As confusing as it would seem, Scenario 1 was not the first scenario to be conducted. However, the scenarios would be ranked and conducted in order of complexity, which gave the drone pilots time and an opportunity to practice with the system before being thrown into the more complex ones.

Scenario 1

Figure 16 Scenario 1 tracking

Scenario 1 was based on the demonstration of UTM equipment for long-haul inspection flights, thus it is relevant to include the Podium funded MUGIN UAV's.

The intention was to fly both VLOS and BVLOS from an automated flight plan, which had been defined beforehand. The VLOS Flights concentrated on doing a complete survey of the airport premises, while the BVLOS flights did a field inspection in EK R OD1. Thus, the restriction zone was fully activated. Thought into a real-life context, these types of long-haul inspection flights could be BVLOS inspection of fields where the crops need to be accounted for. This could be the counting of pumpkins, which has been done as a research project in 2018 (sdu.dk, 2018)[i]. On a more general term, these types of long-haul flights will be useful to the industry, as it increases flexibility and range for UAV solutions.

During these flights the SDU Sky-Watch Cumulus V1 and the Integra MUGIN drone flew simultaneously. The latter flew VLOS, while the former flew BVLOS.

Results turned out to be useful, as it showed how the tracking technology and UTM system proves a useful addition to these types of flights. When flying BVLOS, it is an extra guarantee that a supervisor can monitor and guide throughout the run.

Furthermore, the tracking technology and UTM system is useful in monitoring a larger platform such as the MUGIN.

Limitations:

The number of flights would be limited to 1, as the airport could not be closed entirely for a longer period of time. This puts a constraint on the fact that the scenario was not repeated to rid of any sources of error. However, the BVLOS flights have been conducted before by SDU, and they reported back that no deviations from their flight path occurred, which could be monitored as well.

Quality:

As mentioned above, the limited amount of data from this particular scenario can have an impact on the quality of the results, as the scenario was not repeated. However, all systems were up and running, the flights were planned, and everything went just as they did during the other scenarios. Mind you, that flight planning via the app had taken place several times before, as all flights during the demonstration period focused on resetting the scenario after each run. In the bigger picture, the flight planning phase and execution was thoroughly tested.

Significance:

In terms of the significance of this particular type of flight, both the BVLOS flight and the flight with a larger type of drone is interesting, as BVLOS must be expected to be something that will take place on an ever-increasing scale. BVLOS is the type of mission that is highly sought after from all sorts of industries, as it would increase the usage of drones. However, gaining permission for BVLOS flights today is rather difficult. Even for the flights in question, it was difficult to gain an approval, and external mission monitoring would be a mitigating factor.

In terms of the VLOS flight with the bigger MUGIN platform, it is estimated that drones of this size with a greater MTOW that requires special permissions could also face mitigating factors by the sheer fact that they are equipped with tracking technology. Integra uses these large types of platforms in remote areas, and it would be beneficial to record the entire flight, especially to monitor if anything goes wrong.

Scenario 2

The key objectives of the scenarios were to deliver smaller packages via pre-planned routes and to demonstrate how UTM may add an extra layer of security and surveillance in relations to UAV package deliveries.

The scenario had to deal with simulated scenarios where, at some point in time, the airspace will see various types of UAV flights taking place in shared airspace. Thus, it will be necessary to deploy a number of additional UAV's of various types and sizes. The scenario must see the deployment of at least 1 other multirotor UAV and a fixed wing UAV.

Limitations:

The scenario was initially set out to be autonomous, which could not be possible because of current legislation. Instead the scenario was conducted automatically with a drone pilot ready to intervene.

As with all the scenarios, the shear fact that the demonstrations took place in the airport, would see some limitations to how true to real-life it was. However, it is estimated that a drone delivery would look like this in real life.

Quality:

In terms of the other ordinary flights, it is estimated, that it is highly useful to have a supervisor warning the pilots, if the cross the boundaries of any delivery flights. Drone pilots were warned via radio about the delivery flight. Speculating about the delivery flight as being autonomous, it is highly helpful to being able to monitor the flight from a central point. In terms of a company deploying an entire fleet of delivery drones, the supervisor could both be the company while simultaneously be an authority. As a fleet management system, the UTM system works well.

Significance:

It is significant to demonstrate how a UTM system works in a package delivery scenario. With such notable players in the market as Amazon and the like experimenting with deliveries, it is safe to say, that it will be the future. A UTM system for fleet management and for general supervision is needed, if this one day should be reality.

Scenario 3

Figure 17 - Scenario 3

The aim of the scenario was to demonstrate the use of the UTM system in connection to inspection tasks within the airport. For the scenario it is important to simulate an operating airport as the inspections must reflect how UAV's with UTM could be used as a tool just like the conventional rolling stock and equipment found in an airport today. Missions were conducted VLOS as the main goal was to limit the use of fossil burning vehicles to make the inspection rounds. Not to investigate how to reduce the man-hours used for the inspection of the fences. It could be a future point of investigation, as artificial intelligence may contribute to fully autonomous fence inspections in the future. However, it was not within the scope of these demonstrations to investigate that.

Limitations:

A true airport demonstration scenario would involve the airport to be open with flights taking off and landing while doing the fence inspection. However, rules would not permit, even though there was a safe distance to the runway and all procedures were put in place.

Quality:

Just as the previous scenario, speculations about the fence inspection flight as being autonomous once it becomes reality, it is would be helpful to monitor the flight from a central point. In terms of an airport deploying drones doing inspections somewhere in the airport the supervisor could both be a member of ground handling or the maintenance crew of the airport while simultaneously being an authority. Quality-wise it could be speculated that scenario 2 and 3 could be merged, as they are fairly similar in built-up. However, it is apt to say that some of the aspects from either one of the scenarios could be disregarded, if focus solely lay on autonomy. The nature of the scenarios was different, as they will be operating in very different environments. For this scenario, the drones would operate within an airports security parameters, while the former scenario would regard safe flights within urban and rural environments.

Significance:

Every day, security must do fence inspections to ensure that the area is impenetrable to outsiders. This is done by car, which both takes time, restrains man-hours and pollutes. By conducting the scenario, it gives recommendations towards what should be put in place in order to release the drones in airports in the future. Various stakeholders are awaiting the results

Scenario 4

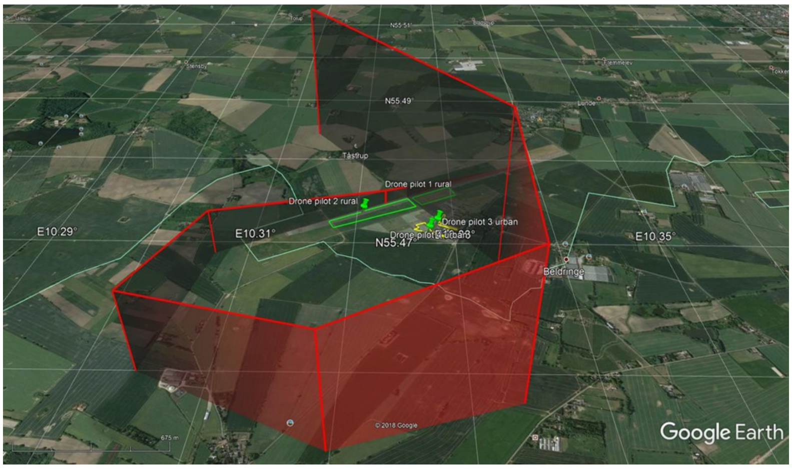


Figure 18 - Scenario 4

The aim of the scenario is to demonstrate the UTM system in operations nearing mission types that are similar or close to similar to operations that are conducted in general on a daily basis today through e.g. different types of inspection missions by various private actors. These types of missions are common among small to medium sized companies who use UAV's as a tool. Thus, the use of UTM in this type of scenario may uncover to what extent a UTM solution ensures coordination and deconfliction between various types of drones in a specific area.

Simultaneously, Scenario 4 formed the basis for testing with the inclusion of general aviation for a number of playthroughs of the scenarios. With the inclusion of general aviation into the scenario, the aim here was to demonstrate how the Unifly system differentiates between UAVs and conventional air traffic in a simulated mixed traffic pattern. For the scenario, it will be required that the Unifly system is able to verify the altitude of both general aviation and UAVs.

The scenario was thus divided into 4-1 and 4-2 where 4-1 was the least complex with ordinary inspection flights, while 4-2 saw the inclusion of general aviation.

Limitations:

For 4-1 the only limitation, which hindered the most agile form of urban flights around the hangar areas was the fact that you could not get an automatic approval. In an ordinary urban environment, the system should automatically grant permission to all involved about ordinary VLOS inspection flights. This could not be demonstrated, which might give some discrepancies between the demonstration and future real-life scenarios. All scenarios could generally not be automatically approved, as they would be limited by the airport in itself.

During the demonstration of 4-2, the fact that the ARTAS feed could not be established, proved to be a minor rewrite of why the demonstration should be conducted. The original idea was the simultaneous flights of drones and general aviation. In the new setup the inclusion of general aviation shifted the focus to testing the tracking technology and how it could be used by both larger drones and general aviation.

Quality:

As mentioned above, the ordinary inspection scenario did not bring much more information about using the system in such a scenario than had already been demonstrated in previous scenarios. However, the system got a run-through once more, and with the focus on simultaneous VLOS inspection flights, the time could be spent on assessing what the system would look to operations going on today.

Figure 19 - Scenario 4

For 4-2, only one drone was deployed, while the plane flew some rounds above the site. With crew spotting if they could see the drone, and with an active DroneID in the plane, the take-away from the flight contributed to assess how the DroneID could be used as a conventional tracker for planes and larger high-altitude drones. The results from the flight contributed positively to insights into the tracking technology and the ability to monitor flights via Drone ID's.

Significance:

It is no secret that it is highly sought after to have a solution to mixed traffic patterns. In other demonstrations, the UTM system has proven to demonstrate that the system can be used to monitor both GA and drones at the same time. In terms of investigating the tracker technology, it has been important to uncover that the tracking technology can be used for drones of the future and for minor aircraft that need some sort of tracking if they are not equipped with the conventional kind.

It is significant to notice that even though the scenario was rewritten, important benefits and limitations have been uncovered.

Scenario 5

During emergency responses drones are being used to a larger extent as a tool get an overview of the situation at hand. These types of missions don't usually require a UTM based system, as only one department of the respective emergency services use a drone. However, the technology is beginning to become more widespread, and there is a possibility that more than one drone will be deployed during an emergency event from both police, fire departments etc. Furthermore, it is relevant to investigate how more drones in the air could help emergency services get an even better overview.

Furthermore, it was tested how the system could work with arranging no-fly zones for the emergency services. This included the emergency services stakeholders having the supervisor system with them in the field.

Thus, the scenario simulated different kinds of emergency scenarios where more than one drone was deployed during the quick response.

Limitations:

Quickly, the scenario proved to be too well-organised for the participating emergency services, as they could not grasp how they should handle all that planning. They understood the need for flight planning in ordinary circumstances and agreed to plan a couple of flights. However, a lot of time went with discussing what an emergency UTM system should be able to do.

One of the main disadvantages of having a simulated emergency is the lack of emergency, which then only would give the stakeholders the ability to take the drones for a flight. Often their missions will be deploying the drone and making it hover for a longer period of time the same place. While doing so during the simulation, the crew tested whether it was possible to use the supervisor system. It quickly turned out to be too complex for field work. And the idea of using the supervisor system in the field was dropped.

Quality:

While the quality of the scenario was limited to some ordinary types of flights, the quality of the discussions regarding how an emergency response UTM system should be built. All inputs were something that had not been entirely uncovered for the tested system, which only is fully compatible with ordinary types of flights now and in the near future. The Emergency services' wish list for a special UTM system was:

- Mission planning and take-off should be as easy as possible.
- Ideally speaking there should be no mission planning.
- Sentry mode cannot be used either, as it would take up time from emergency leader or an extra person.
- It is far too complicated setting up a no fly zone for quick response
- Ideally speaking the no-fly zone should be set up, when the emergency drone takes off.
- It should only be rescinded when the mission is over again.
- The stakeholders do not care about trespassers just as long as they stay away from their mission area.
- Ideally speaking the Drone ID's should not be accessible to tampering

Significance:

As a system, a special Emergency UTM system would be significant in terms of setting up ad-hoc no-fly zones. The significance of the tests highlighted the fact that the UTM system is not necessarily a one-size fits all. In order to gain legitimacy for emergency services, the system must be fitted for their specific purposes. It might not have been within the scope of this project to uncover this and it may not be within the U-space strategy. However, it could be a useful spin-off for other projects in the future.

A.3.5 Conclusions

In general, it can be said that the actors, supervisors and flight crew were easily and quickly trained on the UTM system. The system was already experienced as being very beneficial for the supervisor. For the flight crew improvements have to be made to the system to be able to experience these benefits as well. It was clear to all participants that a system like this is needed in the future, that it should be mandatory and that the authorities should seek for one common system. During the demo flights the drone trackers and Unifly system performed well together. They showed up instantly in

Sentry mode. The Sentry system gave the supervisor a good situational awareness and functioned well as a planning tool. Furthermore, the online processing of approvals also seemed very flexible.

Assuming the perfect system will be implemented in future the benefits are clear. In the future the perfect system will increase situational awareness and safety. In the future system it would be possible to communicate entirely through the system (e.g. If you need additional information as a supervisor, you can request it. For instance, you could request permission and attach an entire SORA beforehand), furthermore, it will be possible to have regulatory eyes on drone traffic at all times, if traffic is monitored and recorded.

A.3.6 Recommendations and requirements

Following requirements were stated to be able to improve the system. Please note that in the consolidated demonstration report a distinction will be made between recommendations applicable to the overall U-space concept and architecture, and requirements that are more applicable to the user experience of a particular product:

1. Requirements and recommendations

    1.1. Requirements for the Flight crew

For the mission preparation phase, the following requirements were stated:

- System shall indicate what documentation is additionally needed for BVLOS to avoid additional requests (clear visibility on what information is needed for what mission-local)
- More editing tools for area definition (delete points, areas and more) are needed
- In mission preparation, other fly zones shall be visible to be aware of an eventual violation.
- It shall be possible to locate pre-planned flights even if the scheduled takeoff time has passed before the drone actually takes off

Following requirements/recommendations were stated for the mission execution phase:

- Drone shall be visible on pilot view map
- No-fly zones shall be visible for pilot
- Pilot shall be able to see other planned flights in the area
- Possibility to communicate via the App (e.g. being told when the flight is approved or rescinded etc.)
- The system should be able to be used simultaneously (integrated) with the drone software to accommodate one-person mission
- Information about no-fly zones, other planned fly-zones, weather forecast, altitude of the drone, location of the drone and warnings about unexpected events shall be available

    1.2. Recommendation for the Supervisor system

- Collision alert should only be active when in fly mode (not when in landed mode)

- Overlapping areas shall be visible
- The system should support to respect restricted areas
- The system shall notify the pilot if the flight permission was cancelled by the Supervisor
- Supervisor shall have required information available at one glance and not to have to switch between “windows” (e.g. The status of the drone (flying / landed) shall be easily identifiable without switching windows)

1.3. General system requirements/recommendation for the system

- It would be good to be able to apply all zone filters at the same time rather than having to go through and select them individually.
- The integration of regular aircraft and drone traffic should be highest on the agenda
- A reliable system and trackers that turn on automatically when the drone is turned on. Tracker and UTM system go hand in hand.

1.4. Procedure recommendations and requirements

- Tool usage in connection with emergency service has still to be investigated as emergency service have time critical missions
- Procedures (and technical implementation) for faulty trackers have to be defined
- Procedures/Phraseology between Supervisor / flight crew/ AFIS have to be defined (e.g. if Supervisor notifies about another drone in the area)
- BVLOS permission request has to be improved
- Training campaign has to be planned

A.3.7 References

[1] PODIUM VLD Revised Demonstration Plan (version 02.00.01, dated 02/04/2019)

[2] PODIUM Concept & Architecture description (version 02.00.01, dated 05/04/2019)

[3] Guidance for U-space recommendations and conclusions (version 01.00, dated 04/07/2019)

[4] PODIUM Odense Pre-Demo Mock-Up Report (version 01.00.01, dated 08/03/2019)

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i https://www.sdu.dk/en/om_sdu/fakulteterne/teknik/nyt_fra_det_tekniske_fakultet/droner_sikrer_flere_graeskar