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PODIUM

PROVING OPERATIONS OF DRONES WITH INITIAL UTM

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

Abstract

The Proving Operations of Drones with Initial UTM (PODIUM) is a SESAR/Horizon 2020 Very Large Scale Demonstration Project, 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 Marknesse and Eelde. The report describes the work performed, the main results, and most important conclusions and recommendations from the individual site perspective.

The demonstration was led by NLR and consisted of 28 drone flights conducted within the Netherlands RPAS Test Centre NRTC and in Groningen Airport Eelde class C CTR during 4 days from 14 May to 4 June 2019. From these demonstrations it is concluded that the concept of U-space is clear and acceptable, despite software and HMI limitations. The technical feasibility of the pre-flight U-space services proved sufficiently mature, while in-flight services need further consideration. In terms of performance, it is concluded that U-space services as an add-on to normal operations increase the workload, the (non-ATC) supervisor role can only be pragmatically implemented through an automated system, and safety may be compromised by insufficient timeliness and completeness of information and technical issues for which standards are lacking. Based on these conclusions and additional observations various recommendations are made.

The contents of this individual site demonstration report will form part of the overall Demonstration Report for PODIUM, – addressing five sites across Denmark, France and the Netherlands -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 the Netherlands describing the work performed, the main results, and most important conclusions and recommendations.

The main objective of the demonstration flights in the Netherlands was to assess how current U-space systems and technology can cope with unexpected situations both in a rural and ATC controlled airport environment. For this, 28 drone flights were conducted within the Netherlands RPAS Test Centre NRTC and in Groningen Airport Eelde class C CTR during 4 days from 14 May to 4 June 2019. From these demonstrations and subsequent analysis it is concluded that the concept of U-space is clear and acceptable, despite software and HMI limitations. The technical feasibility of the pre-flight U-space services proved sufficiently mature, while in-flight services need further consideration. U-space services as an add-on to normal operations increase the workload and the (non-ATC) supervisor role can only be pragmatically implemented through an automated system. Safety may be compromised by insufficient timeliness and completeness of information and technical tracker issues. For these aspects standards are lacking.

Based on these conclusions it is recommended to:

- Ensure that the operational flight plan can be used as an ICAO flight plan
- Define and implement one unique rule-based scheme to determine the level of priority
- Introduce reliable direct communication between the supervisor/ATC and the crew
- Develop a regulatory framework enabling automated flight approvals
- Develop standards for equipment, software and data of which failure reduces safety to an unacceptable level
- provide minimum standards for transponders considering the drone characteristics

Furthermore, deviations from the initial plan and unexpected events during the demonstration, including a Helicopter Emergency Medical Service (HEMS) helicopter scramble, transponder outages and the need to use a mobile phone as back-up. Observations from these events yielded the additional needs to:

- respond immediately to ATC clearances, also without using the U-space system
- be able to communicate directly between the drone pilot and ATC/supervisor
- prevent that multiple users have access to the same (supervisor) session at the same time
- tune lost link procedures to the local normal and non-normal procedures
- assess the suitability and reliability of a mobile phone as (back-up) communication mean

The contents of this individual site demonstration report will form an appendix of the overall Demonstration Report for PODIUM – addressing five sites across Denmark, France and the Netherlands - 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 A EXE-VLD-EEL-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 (version 02.00.01, 02/04/2019) [1] which is further summarised in section A.1. The actual demonstration flights deviated at some points from the planned activities. These deviations are detailed in section A.2. Finally, section A.3 presents the demonstration results including the synthesised conclusions and recommendations.

A.1 Summary of the Exercise Plan

A summary of the exercise plan is derived from [1] focussing on the exercise description and scope, objectives and success criteria and the operational scenarios in the sections hereunder.

A.1.1 Exercise description, scope

Overall approach

The exercise consisted of several drone flight demonstrations conducted within the Netherlands RPAS Test Centre NRTC and Eelde class C CTR during 4 days from May to mid-June 2019. These demonstrations mainly involved drones operators/pilots operating various drones (multi copter and fixed wing) in VLOS and BVLOS scenarios in which 'unexpected' situations occur with the aim to demonstrate how U-space can cope with them.

Figure 1 Group photo impressions

Services used

The demonstrations at NRTC and Eelde were planned to use the following services as described in Ch. 9 of the PODIUM Concept and Architecture Description, see Par. 6.4.6.2 of the PODIUM Demonstration Plan [2]:

Table 1 Services addressed

Service	EXE-VLD-EEL-004-SC1	EXE-VLD-EEL-004-SC2	EXE-VLD-EEL-004-SC3
	Mission priority	Update mission plan surrounding drones	Update mission plan ATC instructions
E-registration (9.2.1)	X	X	X
E-identification (9.2.1)	X	X	X

Service	EXE-VLD-EEL-004-SC1 Mission priority	EXE-VLD-EEL-004-SC2 Update mission plan surrounding drones	EXE-VLD-EEL-004-SC3 Update mission plan ATC instructions
Drone location surveillance and tracking (9.2.2)	X	X	X
Automatic flight plan validation (9.2.3)	P	P	P
Automatic and manual flight permissions (9.2.4)	-	X	X
Generation and management of no-fly zones those become active while the drone is in flight (9.2.5)	P	P	-
Generation and management of no-fly zones based on aeronautical information (including NOTAMs) and aviation regulations (9.2.7)	X	P	P
Conflict Detection / Alerting (9.2.14)	P	P	P
Other; DTM/ATM Interoperability	-	X	X

In the table above the X marks services in which all requirements as described in [2] were shown, the '–' were not planned to be shown in that specific scenario and those partially shown are depicted as P. Of this latter category the aspects that were not shown are listed hereunder:

- Automatic flight plan validation (9.2.3)
  - *PODIUM-SERV-REQ-9:* PODIUM DTM System shall automatically check the detailed flight operation intentions against the airspace structure, national and local rules and registration of the applicant in the State database. Although shown, some information was missing*.
  - PODIUM-SERV-REQ-10: PODIUM DTM System shall analyse the compatibility of flight plan (against other flight plans submitted and/or rules/regulations applicable) requests before the flight plan can be accepted/rejected.
  - PODIUM-SERV-REQ-11: In case of incompatibility (with other submitted flight plans and/or rules/regulations applicable) PODIUM DTM System shall provide feedback to the drone operator (acceptance/rejection).
- Automatic and manual flight permissions (9.2.4) were not available during EXE-VLD-EEL-004-SC1 and where made available for the subsequent demonstrations.
- Generation and management of no-fly zones those become active while the drone is in flight (9.2.5)
  - PODIUM-SERV-REQ-23: PODIUM DTM System shall inform PODIUM DTM Stakeholders on no-fly zone activation and deactivation.
- Generation and management of no-fly zones based on aeronautical information (including NOTAMs) and aviation regulations (9.2.7)
  - PODIUM-SERV-REQ-27: PODIUM DTM System shall relay ATM information, such as aeronautical information and aviation regulations into no-fly zones (activate, deactivate, change size/shape). Although shown, some information found to be

missing by the actors. This was due to the fact that basic NOTAM parsing is available on the PODIUM environment. Advanced parsing (analysing the E-line and the D-line in combination with the Q-line) was not available on this environment

- Conflict Detection / Alerting (9.2.14)
    - PODIUM-*SERV-REQ-38:* PODIUM DTM System shall be able to detect the following conflicts:
        - ...
        - Drone leaving geocaged zone;
        - Drone entering geofenced zone.
    - PODIUM-*SERV-REQ-39:* In the event of conflict being detected, the PODIUM DTM system shall be able to send alerts to the involved pilots via PODIUM DTM HMI

*Because of its history, manned aviation has a specific set of airspace and airport data, whereas unmanned aviation (drones) needs additional data which is linked to potential ground risk, privacy, security and nature. These types of data sets are difficult to find (and sometimes non-existing). Available data on the PODIUM environment for the Netherlands was limited to:

- Airspace data (CTR, LFA, Danger, Restricted, Prohibited) (via Lufthansa db and pdok.nl for the simulated forced landing areas (made available in the system as LFA))
- Controlled and uncontrolled airports and heliports (via Lufthansa db, OSM and pdok.nl)
- NOTAMs
- Nature areas (via pdok.nl: natura 2000 and national parks)
- Highways (via pdok.nl)
- Roads (via pdok.nl)
- Railroads (via pdok.nl)
- Harbours (via pdok.nl, OSM and havenraad.nl)
- Build-up areas (via pdok.nl)
- Industrial areas (via pdok.nl)
- Engineering structures (via pdok.nl and OSM):
- OpenStreetMaps

Systems used

The demonstrations at NRTC and Eelde were planned with the systems as described in the revised PODIUM Demonstration Plan [1] and were actually performed with the following:

Table 2 Systems used

System	EXE-VLD-EEL-004-SC1 Mission priority	EXE-VLD-EEL-004-SC2 Update mission plan surrounding drones	EXE-VLD-EEL-004-SC3 Update mission plan ATC instructions
Drones			
• Fixed Wing	-	1	1
• Multi-rotor	3	-*	-
• Helicopter	-	-	-
UNIFLY system populated with airspace info. and regulations, etc.			
• UNIFLY Sentry (authorities/regulators/ATC)	1*	1	1

	EXE-VLD-EEL-004-SC1	EXE-VLD-EEL-004-SC2	EXE-VLD-EEL-004-SC3
System	Mission priority	Update mission plan surrounding drones	Update mission plan ATC instructions
• UNIFLY Pro (drone operators)	3	1	1
• UNIFLY Launchpad (drone operators) *	-	-	-
Airbus System			
• RT Data Collector (U-space surveillance Tracker And Server)	X	X	X
• Cooperative tracking	X	X	X
• Non-cooperative tracking	-	-	-
• Recording	X	X	X
• Orange GSM connectivity	X	X	X
Tracker			
• uAvionix (ADS-B, 1090 MHz)	3	1*	1
• Other; uAvionix Ping Station	1	1	1

*Deviated from initial plan. This is further detailed in section A.2.

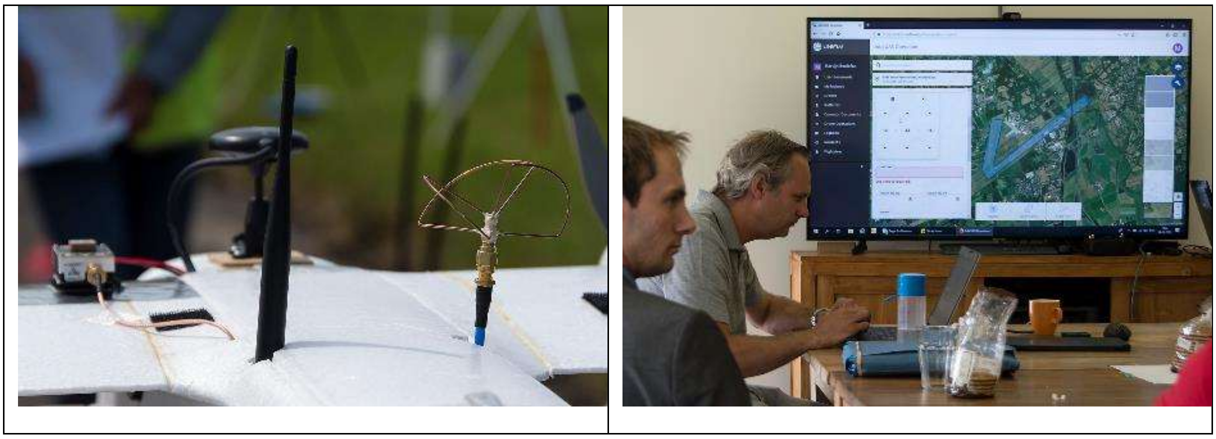


Figure 2 Transponder on drone (left) and flight planning impression (right)

A.1.2 Exercise Objectives and success criteria

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

Table 3 Demonstration Objectives and success criteria

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	Covered for nominal situations in VMC daylight operating conditions	Assess the operational feasibility and acceptability of conflict detection/alerting service between drones through the U-space system Assess the operational feasibility and acceptability of updating mission plan through the U-space system when in flight	The roles and responsibilities of the involved actors (individual and at the level of the team) are clear and acceptable The tasks and procedures of the involved actors (individual and at the level of the team) are clear and acceptable The technical systems proposed are usable (HMI) and acceptable (e.g. trust in the systems, limitation of human errors) to end users The technical systems proposed support the end users' performance in order to achieve their tasks in an efficient, accurate and timely manner
OBJ-VLD-POD-002 Technical feasibility	CRT-POD-002-001 CRT-POD-002-002 CRT-POD-002-003	Covered for nominal situations in VMC daylight operating conditions	To demonstrate that the various technical systems (transponder tracking devices and the U-space/UTM system) meet critical functional and performance	The various systems provide the information required as it is needed and when it is needed The various systems perform as expected even when used to

	CRT-POD-002-004		requirements to cope with high priority drones and (ad hoc) deviations in a CTR environment	supervise simultaneously multiple drones
OBJ-VLD-POD-003 Safety	CRT-POD-003-001 CRT-POD-003-002 CRT-POD-003-004	Covered for nominal situations in VMC daylight operating conditions	Assess the contribution of conflict detection/alerting and flight mission update during flight services to ensure safety of operations	Demonstrate the safe integration of drones through increased awareness of all airspace users, strategic de-confliction and conformance monitoring Demonstrate that conflict detection/alerting and flight mission update during flight services contribute to the reduction of air risk in uncontrolled and controlled CTR airspaces Demonstrate that that conflict detection/alerting and flight mission update during flight services contribute to the reduction of incursion into no-drone zones nearby in uncontrolled and controlled CTR airspaces
OBJ-VLD-POD-004 Security	CRT-POD-004-001 CRT-POD-004-002	Covered for nominal situations in VMC daylight operating conditions	Assess applicability of SECOPS proposed security mitigations to PODIUM	SECOPS security mitigations that are applied in PODIUM (if any) are documented and integrally assessed in terms of operational and technical acceptability (OBJ-VLD-POD-001 and -002)
OBJ-VLD-POD-005 Standards & regulation	CRT-POD-005-001 CRT-POD-005-002	Covered for nominal situations in VMC daylight	Document the impact of current standards and regulations on the demonstrated U-space services and applied	Bottlenecks (if any) in the current regulations are identified for future application of

		operating conditions	like tracking systems (in particular for conflict detection/alerting and flight mission update during flight services)	demonstrated U-Space services in uncontrolled and controlled CTR airspaces and in particular on the application of transponder like tracking systems
OBJ-VLD-POD-006 Initial benefits assessment	CRT-POD-006-001 CRT-POD-006-002	Covered for nominal situations in VMC daylight operating conditions	To collect initial feedback from the different stakeholders on the benefits/limitations of the U-space services addressed and in particular conflict detection/alerting and flight mission update during flight services	Initial benefits and limitations of the U-space services addressed in terms of cost effectiveness (e.g. potential time, effort, cost saving) are identified Initial benefits and limitations of the U-space services addressed in terms of capacity (e.g. potential for enabling more simultaneous flights)

A.1.3 Exercise Operational scenarios

Table 4 Demonstration Netherlands Exercise layout

Description	**EXE-VLD-EEL-004** consisted of several drone flight demonstrations conducted within the Netherlands RPAS Test Centre NRTC and Eelde class C CTR during 4 days from May to Mid-June 2019. The flight demonstrations involved drone operators/pilots operating various drones (multi copter and fixed wing) in VLOS and BVLOS scenarios in which ‘unexpected’ situations occurred with the aim to demonstrate how U-space can cope with these. **Scenario 1**: Within the NRTC’s restricted uncontrolled airspace, over rural area, there are two multi-copter drones, operated by independent operators in a VLOS operating zone without conflict. One of these is operated manually, and the other flies in an automated mode following waypoints. A third drone, with higher priority, needs to cross the operating areas of the other two drones. **Scenario 2**: Within controlled class C CTR of Groningen Airport Eelde a fixed wing drone takes-off from the airport for a flight on a pre-planned BVLOS trajectory. After take-off the crew is informed by a remote observer that the initially planned landing location is unavailable and the drone has to divert to its pre-planned alternate landing location. **Scenario 3**: Within the controlled class C CTR of Groningen Airport Eelde a fixed wing drone takes-off from the airport for an automated flight on a pre-planned BVLOS trajectory for circuit training. After take-off the crew is informed by ATC that the runway is unavailable. It was planned that this would be communicated through the U-space system with additional verification through regular R/T or mobile phone communication.
Demonstration Technique	Live Trial
KPA/TA Addressed	Flight Efficiency, Safety
Number of flights	30 (foreseen)
Start Date	14/05/2019
End Date	04/06/2019
Demonstration Coordinator	NLR
Demonstration Platform	U-space service (Smartphone application, Desktop application, U-space Service Provider application); Trackers (ADS-B) ; Drones (multi-copter, fixed-wing)
Demonstration Location	EHGG and NRTC The Netherlands

Figure 3 Eelde impressions from Tower, BVLOS pilot and drone

A.1.4 Exercise Assumptions

Table 5 Demonstration Exercise Assumptions

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

A.2 Deviation from the planned activities

The actual demonstration flights deviated from the planned activities on the points as described hereunder.

Deviation #01

Scenario 3: The U-space system was not capable to let ATC communicate the need to divert to another runway through the U-space system, and hence regular R/T was used instead.

Deviation #02

Scenario 3: It was intended that the crew would use the U-space system for diverting to another runway. It appeared that the crew did not have sufficient time for this because the drone was already close to the holding point.

Observation #01: Within a controlled environment, drones shall be able to respond immediately to ATC clearances, also without using the U-space system.

Deviation #03

Assumption POD-A1: The BVLOS procedures were in place but needed fine-tuning during the practice day. A total of 4 crew members were needed. One (indoor) BVLOS pilot, one (outdoor) safety VLOS pilot, one observer and one test coordinator. The test coordinator was added to manage the demonstration's timing and sequencing and performed the R/T communications with Eelde tower. The R/T was done by the test coordinator because the design of the flight controls did not allow the pilots to also communicate with ATC.

The crews should comprise of the least number of crewmembers that can fulfil the required tasks with at an acceptable level. Although the fourth crew member was needed, his presence complicated the communication procedures among the crew members, and it would be preferred if the other crewmembers could communicate with ATC and a three-man crew would suffice for normal operations.

Figure 4 BVLOS crew members

Observation #02: When operating in an ATC controlled environment, drone pilots shall be able to communicate directly with ATC.

Deviation #04
Assumption POD-A7: The airport coordination procedures were in place and adapted to the flight demonstrations, but not validated.

During the demonstration flights, the airport was declared Prior-Permission-Required (PPR) by NOTAM, which allowed ATC to suppress all manned aviation.

Deviation #05
The demonstration plan foresaw a minimum of 30 flights for the flight demonstrations, familiarization with the U-space system, testing the equipment, familiarizing the crews with the scenarios, and in case any flights would have to be interrupted due to weather or a technical problem. The following flights were logged:

Date	Location	Type	Registration	Flights	Flight duration (min)	Remarks
15-04-2019	NRTC	DJI M600	PH-1AQ	2	5	Practice runs
		DJI S1000	PH-1LJ	2	15	
		DJI Inspire	PH-2GO	2	14	
		ZoeX4	PH-X1A	5	9	
30-04-2019	EHGG	MTD	PH-1AW	5	38	Practice runs
14-05-2019	NRTC	ZoeX4	PH-X1A	2	9	Visitors day
		DJI S1000	PH-1LS	2	19	
		DJI Inspire	PH-2GO	3	18	
04-06-2019	EHGG	MTD	PH-1AW	5	30	Visitors day

Only 28 flights were needed because there were no interruptions due to weather or technical problems, and because the two practice days proved to be sufficient for preparing the visitors days. In addition, familiarizing the crews with the U-space system could very well be done without live flying.

Deviation #06
It was not possible to provide automatic flight permissions; flight permissions could only be provided manually, by the U-space supervisor.

Deviation #07
Conflict Detection/Alerting in the pre-flight phase was not available; this had to be performed by the U-space supervisor.

Deviation #08
The (mobile) UNIFLY Launchpad for the drone operators was not available; this was mitigated by using R/T voice and mobile telephones.

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.

Table 6 Summary of exercise results

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	Pre-flight • Conclusion #01: The concept of operations regarding flight plan submission and updating was assessed as clear and acceptable. However in practice the software showed limitations and the HMI was not assessed as clear and acceptable.	POK
		Flight execution • Conclusion #02: The U-space interface alone did not suffice as sole means for conflict detection/alerting. It is however evaluated by the different actors that this is due to the limitations of the used software. • Conclusion #03: Mobile application is necessary for flight crews to be able to benefit from the U space system; using a laptop is not practicable in the field, also because connectivity may not be ensured.	NOK

OBJ-VLD-POD-002 Technical feasibility	CRT-POD-002-001 CRT-POD-002-002 CRT-POD-002-003 CRT-POD-002-004	Pre-flight and Flight execution • Conclusion #04: The trackers performed intermittently; hence ATC and Supervisor were not aware of the drone's position at all times. There is currently no standard for the minimum availability of a drone's position. • Conclusion #05: Drones equipped with multiple trackers revealed significant differences between the drone's position as measured by one tracker and the position as measured by the other. There is currently no standard for the minimum accuracy of a drone's position. • Conclusion #06: U-space provides a promising mean of managing drone traffic. However, before implementation several improvements need to be made. More specifically this includes the provision of more information to allow the supervisor to effectively review Permission Requests for approval, including a direct means of communication between the supervisor/ATC and the crew, and to increase the system's technical reliability.	NOK
OBJ-VLD-POD-003 Safety	CRT-POD-003-001 CRT-POD-003-002 CRT-POD-003-004	Pre-flight • Conclusion #07: The crew did not receive all safety related information, and was not informed about other drone operations in the vicinity.	NOK
		Flight execution • Conclusion #08: Occasionally ATC and the supervisor could not track the drone in-flight.	POK
OBJ-VLD-POD-004 Security	CRT-POD-004-001 CRT-POD-004-002	Pre-flight and Flight execution • Conclusion #09: Because of the limited number of demonstration flights, no security related issues could be identified.	n/a
OBJ-VLD-POD-005 Standards & regulation	CRT-POD-005-001 CRT-POD-005-002	Pre-flight • Conclusion #10: The format for submitting an ICAO flight plan for the purpose of a drone flight by internet is not clear and does not matches the operational flight plan as currently defined by the U-space service provider.	OK*

		Flight execution • Conclusion #11: Regulations currently do not allow small drones to be equipped by light-weight low-power transponders (as these, by design, do not comply with all certification standards, i.e. minimum output power), and there are no minimum standards for these light-weight low-power transponders. • Conclusion #12: There is currently no rule based scheme to determine the level of priority of a mission applicable to all U-space systems.	
OBJ-VLD-POD-006 Initial benefits assessment	CRT-POD-006-001 CRT-POD-006-002	• Conclusion #13: The current technology status of the U-space system is more of benefit to operators and flight crews than to supervisors. The supervisor role would benefit from more (or completely made redundant) automation, especially outside of manned controlled aerodrome environments.	POK

* Assessed against the success criteria: *Bottlenecks (if any) in the current regulations are identified for future application of demonstrated U-Space services in uncontrolled and controlled CTR airspaces and in particular on the application of transponder like tracking systems*. As bottlenecks have been identified this is marked as OK. However, this should not be interpreted as a full assessment on potential regulatory bottlenecks, nor that the bottlenecks are resolved.

A.3.2 Analysis of Exercise Results per objective

This section provides a more detailed explanation of the exercise results per objective.

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

The aim of this objective is to demonstrate the impact on human performances through assessment of the operational feasibility and acceptability of the addressed U-space services, notably for resolving conflicts and updating mission plans.

The Eelde scenarios did not include conflicts; hence assessing the operational feasibility and acceptability of conflict detection/alerting service could only be verified by the flight demonstration at NRTC, which involved a high priority drone crossing the airspaces where two other drones were operating. The objective was to demonstrate that the U-space services would detect and resolve this conflict, but for safety reasons this conflict was also detected by visual observations by the crews of the drones and by the supervisors, who informed each other by R/T voice communications.

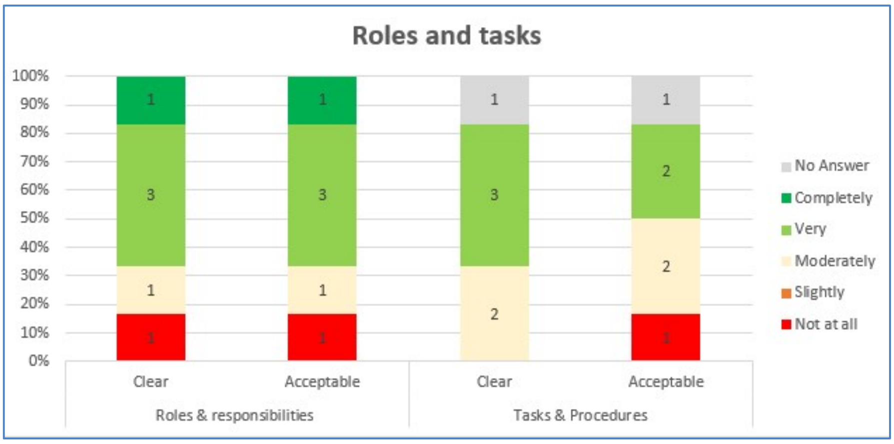
The second criterion, assessing the operational feasibility and acceptability of updating the mission plan by the U-space system, was performed while the drones were in flight. This was demonstrated at NRTC and at Eelde. For reasons of safety, the updating of the operational flight plan through the U-space system was verified by R/T voice communications.

After the flight demonstration, all participants (crews, supervisors and evaluators) were asked to first fill in a questionnaire, and then to discuss this event in a plenary group discussion, focussing on:

1. Whether their roles and responsibilities were clear and acceptable, as well as their tasks and procedures
2. The operational feasibility and acceptability of the system,
3. The timeliness of the provided information, while preparing the mission as well as during mission execution,
4. The accuracy of the provided information, as perceived by the crews and the supervisor, and
5. Whether the respondent had sufficient trust in the system.

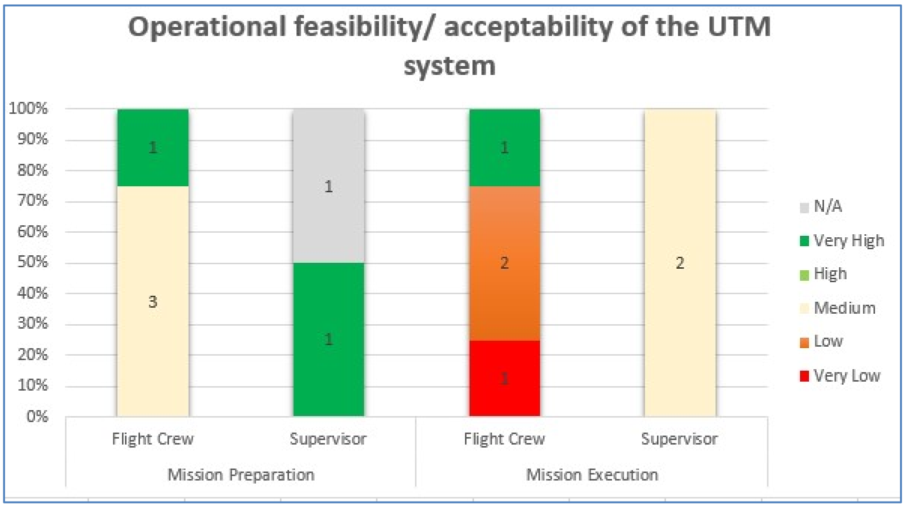
From the textual comments to the questionnaire it appeared that it was difficult to separate the Unifly system from the U-space concept. As far as possible, the following paragraphs address the U-space concept, not the Unifly system. Additionally despite “understanding” the UTM functionalities, the flight crew and supervisor did not feel sufficiently familiar with the UTM system.

<u>Roles and tasks</u>



The diagram shows that the majority of the respondents replied positively (i.e. ‘very’ or ‘completely’) that for them their roles and tasks were clear, while some answers were rated with ‘moderately’. The respondent with the negative answer explained afterwards that this was due to his unfamiliarity with the system, i.e. that he had not had enough preparation/training. Based on expert judgement, comments and observations we can indicate that the actors were less aware of their role and associated tasks in the context of the UTM system, relying almost entirely on their experience in current operations that did not cover all procedures and aspects of the demo exercises.

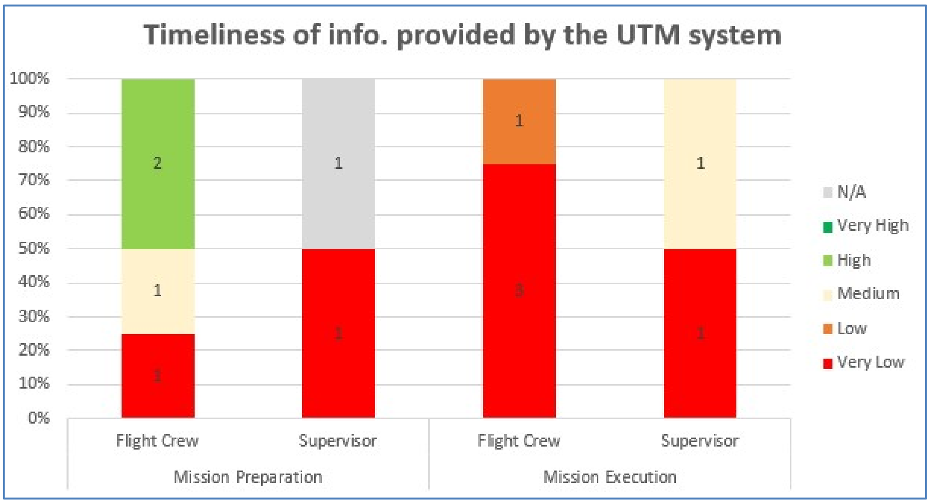
Operational feasibility and acceptability



Although the flight crews gave ‘medium’ scores for the U-space system during mission preparation, they gave ‘low’ scores for the system during flight execution. This is because the flight crew was only trained for applying the U-space services in the ‘mission preparation’ phase, and because for them no U-space system was available during any of the flights, due to unavailability of a mobile application that they could run on tablet/mobile phone. Furthermore, if available it was noted that it would require constant connectivity in the field, which may not be ensured everywhere.

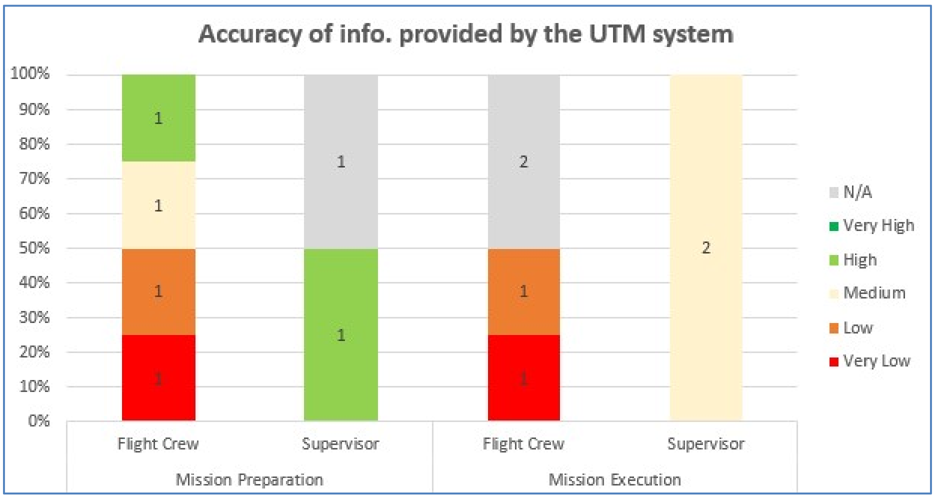
The supervisor had rather more positive and moderate answers for both the ‘mission preparation’ phase and the ‘mission execution one’ as the UTM system allowed the in-flight tracking of the drones from the supervisor position. The supervisor`s input was overall positive with the mention that an enhanced UTM system would represent an added value for the supervisor role, which would help ensure “de-conflicting drone operations”, enhancing their situational awareness.

Timeliness of the provided information



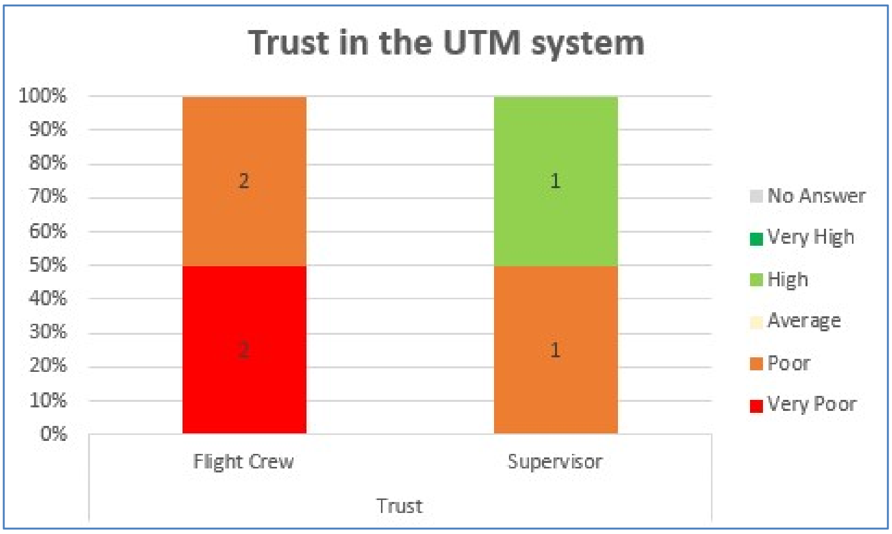
The timeliness question assesses how the different stakeholders perceived the ability of the U-space system to perform all the requested functionalities in time. The majority of the correspondents gave a negative score to this, meaning they were not satisfied with the time the U-space system needed for performing the requested functionalities. This can be explained by the limitations of the system, still needing many updates. Loading of pages took too long and the provision of in-flight data had delays, which yielded a safety risk because the crews did not have up-to-date information. The U-space system provider acknowledged that this needs improvement and is working on updates of the system.

<u>Perceived accuracy of the provided information</u>



The flight crews gave negative scores during mission execution because these services were not available to them in-flight, see Ad 2. Also there were delays in the transmission of data, yielding a safety risk, see Ad 3. The accuracy of the provided information is assessed by questioning the crews and supervisor. The supervisor feedback was positive with “high” and “medium” answers, which reinforce the fact that the current UTM system requires additional and more stable features. Furthermore, a comparison between the drone positions as determined by the U-space system / on board tracker and drone position as recorded on-board the drone’s autopilot system was made. These results are presented in the next section on technical feasibility, limiting this section to the perceived accuracy as obtained through the questionnaires only.

Trust



The flight crews had a negative feedback regarding their trust in the UTM system which is attributed to the fact that for the mission preparation phase the UTM system proposed lacked some of the features that would have enhanced their situation awareness (e.g. availability of NOTAMs, "no fly zones", availability of national rules etc.) that would have allowed for an effective authorisation process. Additionally the UTM services were not available to them in-flight, see Ad 2.

Also there were delays in the transmission of data, yielding a safety risk, see Ad 3. These factors explain the negative score the flight crews gave with regards to trust. The supervisors had each a different opinion, one positive and one negative. The positive answer is attributed to the projection of an enhanced version of the system, as the supervisor answered the question keeping in mind that the assessment went beyond the availability of the UTM system presented in the demo. Overall the conclusion of the participants was that the system represents a good basic idea that "needs to be better implemented".

In addition to these statistical outcomes, there were textual comments in the questionnaires and a plenary group discussion.

For the conflict detection/alerting service the textual comments and group discussions yielded:

- *The roles and responsibilities of the different actors with regards to conflict detection were not 100% clear. The actors indicated not feeling comfortable enough with the UTM alone, and were happy there were still radio and visual checks. The conflict resolution solution (not part of this objective), is also not mature enough for actual implementation.*

- *The users of the UTM system indicated low perceived user friendliness of the HMI. The reasons were mainly the slow speed of loading pages, necessity to manually refresh pages at crucial times, missing of notifications and alerts, and overall not straight forward enough process with too many requirements and inputs. Important to note that this might be due to lack of familiarity with the software systems.*

- *The conflict detection during flight was difficult to identify, as during the demonstration there were some technical issues with the used software.*

For updating the mission plan by the U-space system the textual comments and group discussions yielded:

- *The roles and responsibilities of the different actors with regards to flight plan submission and updating of these flight plans were clear. The main problem however was in the implementation of this process:*
- *The re-planning/re-submitting in flight requires the pilot to take hands off controls. This has an impact on his/her situational awareness, as well as it creates an enhanced workload.*
- *For the supervisor some difficulties were experienced with the filtering of the flights and different requests. It was doable during the demonstration, only because of the low number of drones in the air; with a much larger number of drones flying it is expected that the current system will not be sufficient.*

The conclusions for pre-flight preparations are:

Conclusion #01: The concept of operations regarding flight plan submission and updating was assessed as clear and acceptable. However in practice the software showed limitations and the HMI was not assessed as clear and acceptable.

The conclusions for flight execution are:

Conclusion #02: The U-space interface alone did not suffice as sole means for conflict detection/alerting. It is however evaluated by the different actors that this is due to the limitations of the used software. Conclusion #03: Mobile application is necessary for flight crews to be able to benefit from the U-space system; using a laptop is not practicable in the field, also because connectivity may not be ensured.

2. OBJ-VLD-POD-002 Technical feasibility

The aim of this objective is to assess the Technical feasibility of the various systems (e.g. trackers, Unifly U-space system).

Trackers

Occasionally the supervisor could not track the drone in-flight, severely degrading the supervisor's situation awareness. This shortcoming was probably due to 'inter-modulation' and the subsequent need to regain GPS position after a (steep) turn. This shows that (electrical) integration of the trackers on the drones is not easy: the trackers are not certified for use in manned aircraft and the trackers as well as the drones lack EMI (Electromagnetic Interference) resistance.

Drones equipped with multiple trackers revealed significant differences between the drone's position as measured by one tracker and the position as measured by the other. This is shown in the picture below: for one of the demonstration flights at Groningen airport (EHGG) the GPS position from the drone's autopilot (yellow line) is compared to the GPS position from the tracker (received through an independent ADS-B receiver). For some parts of the flight the data matches, but there are large portions of the flight where a considerable difference exists. Especially after the first turn after take-off (bottom yellow line) the tracker shows an unrealistic straight line. The last valid position seems to be extrapolated based on speed and track (bottom straight red line). Most likely, this is a result of the firmware of the software in the respective tracker. Most GPS receivers have incorporated a position filtering system that extrapolates positions, although a different time-sequencing is noted for the extrapolated data. Comparable behaviour was observed with data from the uAvionix Ping station (which was a different system then the independent ADS-B receiver), made visible in the Unifly U-space system.

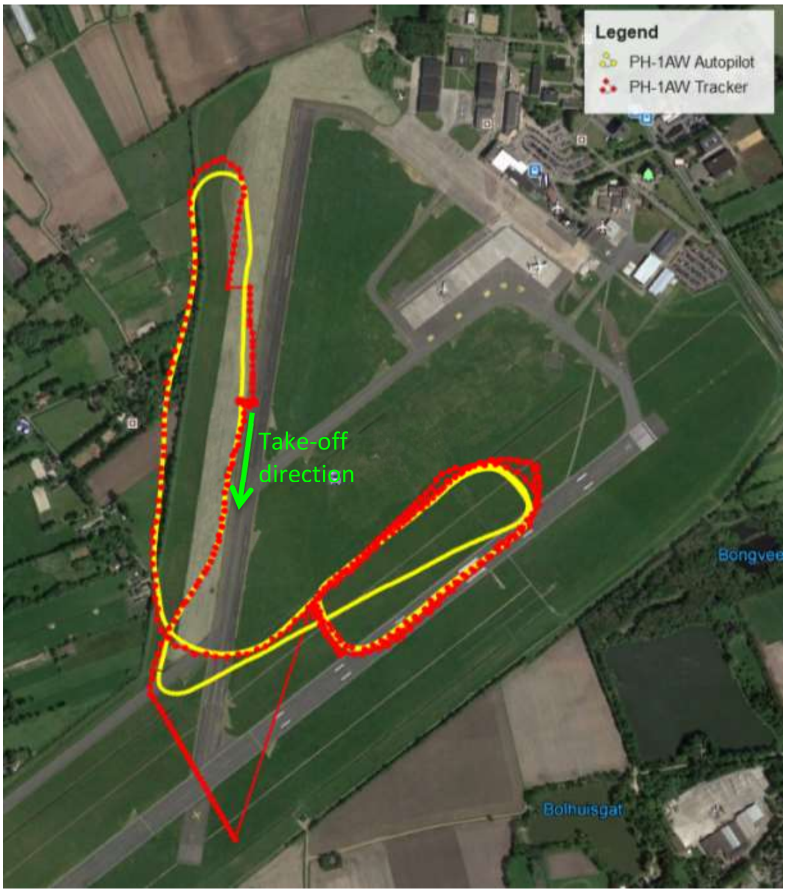


Figure 5 Comparison of PH-1AW GPS position from autopilot (yellow) and tracker (red). Flight at Groningen airport (EHGG) on 4 June 2019, 12:48 UTC.

A similar behaviour is visible in the tracker's barometric altitude. In the following graph the altitude is shown. At time 2625 seconds the altitude starts to increase linearly for about 20 seconds, after which no data is received. At time 2780 seconds the tracker is received again.

Also visible is the fact that the barometric altitude is reported in 25 feet increments.

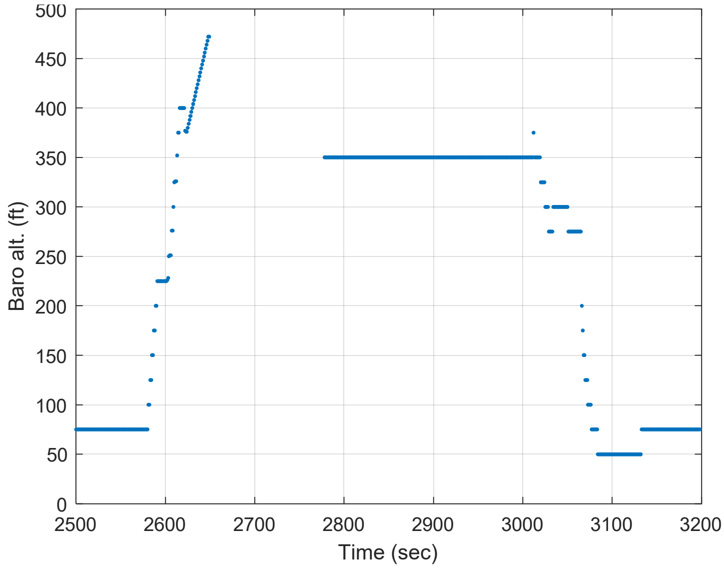


Figure 6 Altitude profile of PH-1AW flight on 20190604 12:48Z

There should be a standard for the minimum accuracy of a drone's position.

Altitude indication in the Unifly U-space system was incorrect (shown to be in feet, but value was actually in meters), but this is a relatively simple error in implementation, probably in translating the flow of information from the uAvionix ground station to the Unifly system. More importantly, the altitude reference of the trackers is unclear. Most likely, the reference for altitude is QNE (1013.25 hPa), which is standard for transponders in manned aviation. This results, for one value of height above ground, in values of altitude that vary with air pressure (QNH): see **Error! Reference source not found.** below. As a result, for an observer of the 'supervisor window', it is difficult to judge whether a system is on the ground or not. For approval of a high-priority operation it can be required to know that other drones are on the ground, or sufficiently low for crossing traffic. With the current altitude indications this is nearly impossible.

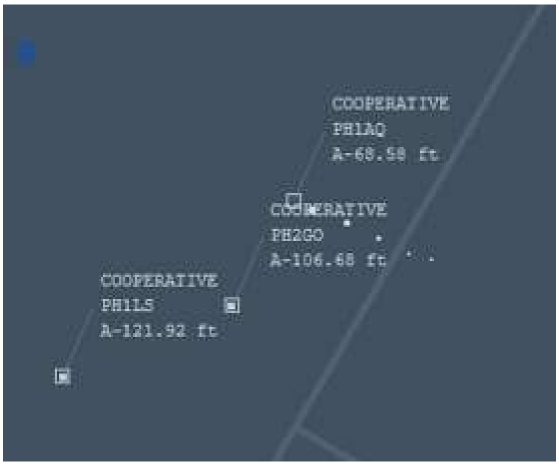


Figure 7 Different height readings for drones on the ground

Unifly U-space system

The foreseen architecture provides a promising mean of managing drone traffic. In the flight preparation phase, it was possible for crews to plan multiple flight areas, overlapping both in space as in time. Although it is also possible in manned aviation to enter multiple flight plans with the same aircraft, the current U-space implementation does not provide a warning or feedback to the crew or supervisor of such overlapping flight requests which would be considered as beneficial and would aid the flight preparation and eases the approval process. In this respect it should be noted that planned areas are not equivalent to reserved airspace.

Figure 8 Overlay of different conflicting planned operations

The link between the planned flight area and the drone flying the operation was difficult to find: clicking on the area only provided the name of the operation. Subsequently that name had to be manually looked up in the Permission Requests section.

Flight areas are not shown in the Flight View when the requested time slot has not yet started. This hinders the strategic de-confliction as done in the manual flight approval process. Also, when reviewing a Permission Request, the planned flight area is visible as a picture, but other requested areas are not shown. As a result, coordination by the supervisor of flight requests for future operations that are close or overlapping in time and space is not possible.

These shortcomings make it difficult for the supervisor to review Permission Requests for approval.

When clicking a flight area or a drone in the Flight View during an operation, the contact information (of the operator) is visible, but cannot be clicked or copied. As a result, contacting the crew becomes a completely manual operation, consisting of finding the telephone number in the flight view and dialling that number. For operations requiring a rapid intervention, as was simulated during the demonstration flights, this leads to a long response time. Feedback from the crew to inform the supervisor that their system has landed is required before approving the high-priority operation. Currently there is no function implemented in the demonstrated U-space system to provide this feedback. As a result crews and supervisor have to rely on a telephone connection, which is time consuming.

After contacting a crew to request a landing to accommodate the high-priority traffic, the crew has no feedback about the time when they can resume their operation. There currently are no means for the crew to contact the supervisor through the Unifly system (other than submitting a flight request). Also, the supervisor's contact information cannot be found. These issues could possibly lead to an increase in the crew's workload or a decrease in their acceptance of the U-space system.

The technical implementation of the Unifly environment is, at the time of the demonstration flights, insufficiently reliable: zooming is slow, sometimes no traffic is shown and there are differences between Chrome and Internet Explorer. A new flight request does not result in a pop-up window or warning on the supervisor screen. A manual 'refresh' of the flight request window is required. For high-priority operations this is considered not to be acceptable. Flight of a drone outside its planned flight area does not result in a warning. Again, these items lead to a decrease in the usability and acceptance of the U-space system.

Conclusion #04: The trackers performed intermittently; hence ATC and Supervisor were not aware of the drone's position at all times. There is currently no standard for the minimum availability of a drone's position.

Conclusion #05: Drones equipped with multiple trackers revealed significant differences between the drone's position as measured by one tracker and the position as measured by the other. There is currently no standard for the minimum accuracy of a drone's position.

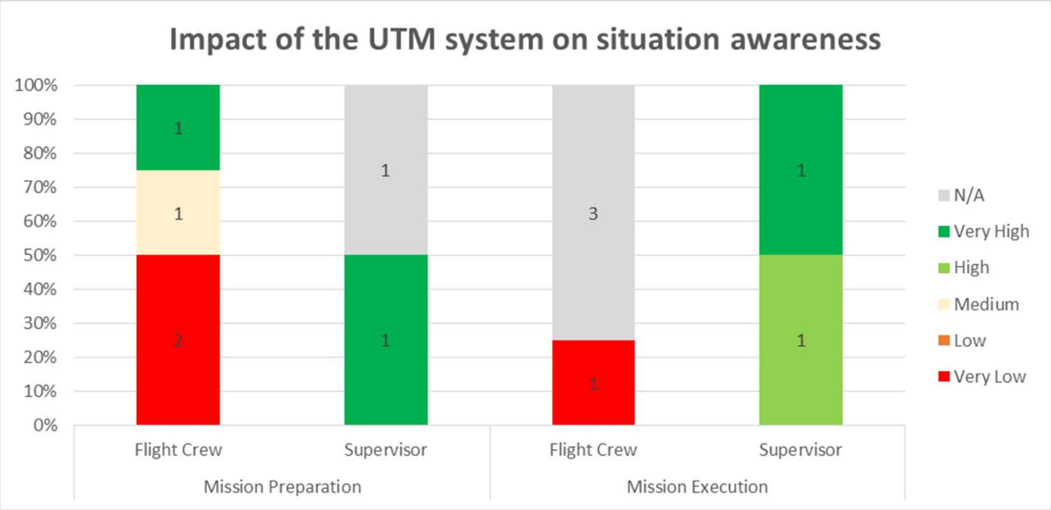
Conclusion #06: U-space provides a promising mean of managing drone traffic. However, before implementation several improvements need to be made. More specifically this includes the provision of more information to allow the supervisor to effectively review Permission Requests for approval, including a direct means of communication between the supervisor/ATC and the crew, and to increase the system's technical reliability.

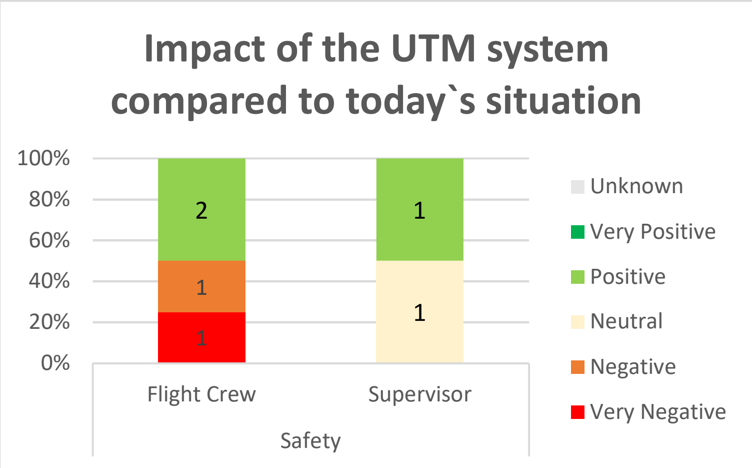
3. OBJ-VLD-POD-003 Safety

The key environment conditions for the PODIUM demonstration flights at NRTC and Eelde are:

- Nominal
- Flight rules: VLOS, BVLOS, VFR, IFR
- Environments: suburban, rural environment, within CTR.

While performing the demonstrations, the following was noted:





For the impact of the U-space system on obtaining situational awareness during mission preparation, the flight crews gave negative scores, also relative to today's situation, because they had no oversight of the other drone operations in the vicinity, and hence did not know which airspace was available for their flight. The impact during flight execution scores N/A because they had no interface with the U-space system at all, so couldn't even monitor their own flight with the U-space system (as stated in Conclusion #03).

After each flight, the crews grew more familiar with the system, and consequently gave more positive scores. This explains the spread in scores (from negative to positive) because the diagrams combine the evaluations of all flights, and hence contain the negative scores from the initial flights as well as the more positive scores from the later flights.

Contrary to the crews, the supervisors did have an overview of all flights; therefore their scores are more positive.

One supervisor scores N/A during mission preparation because the supervisor permission flow was not available during the first flight demonstration, and scores 'very high' when it was available during the second.

The flight demonstrations revealed the following safety issues:

- The airport was declared PPR by NOTAM; however, due to filtering settings the U-space system did not inform the crews about this NOTAM.
- In-flight the supervisor and ATC could track the drone most of the time, but occasionally tracking was not available.

The conclusions for pre-flight preparations are:

Conclusion #07: The crew did not receive all safety related information, and was not informed about other drone operations in the vicinity.

The conclusions for flight execution are:

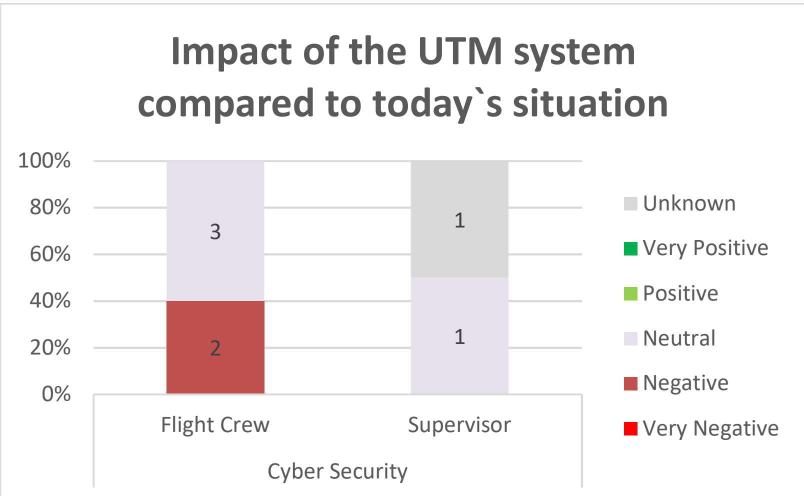
Conclusion #08: Occasionally ATC and the supervisor could not track the drone in-flight.

4. OBJ-VLD-POD-004 Security

During the limited number of demonstration flights, no security related issues were identified.

Initially the objective was to document and assess the security mitigations as proposed by the SECOPS project and applied in PODIUM (if any) in terms of operational and technical acceptability. For this, the PODIUM visitor day was planned simultaneously with the SECOPS demonstration day. However, due to a simultaneous EU/EASA U-space workshop, the SECOPS demonstration had to be postponed. Furthermore, due to classification issues with SECOPS material such an assessment could not be made.

Additionally, security related questions were included in the questionnaire.



The scores for cyber security were negative to neutral or unknown. The only flaw that appeared was that multiple supervisors could simultaneously log-in to the same session, and be presented with different information.

Observation #03: Each U-space session shall be uniquely linked to one user only, the session management shall prevent that multiple users have access to the same session.

The conclusion for security is:

Conclusion #09: Because of the limited number of demonstration flights, no security related issues could be identified.

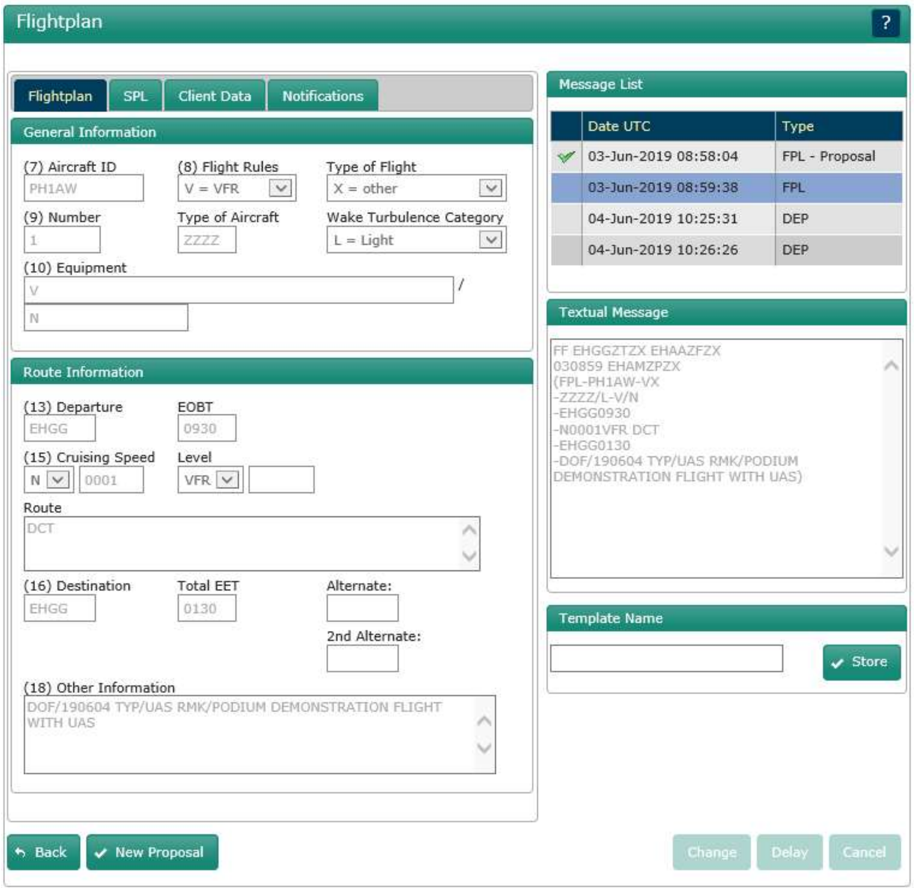
5. OBJ-VLD-POD-005 Standards and regulation

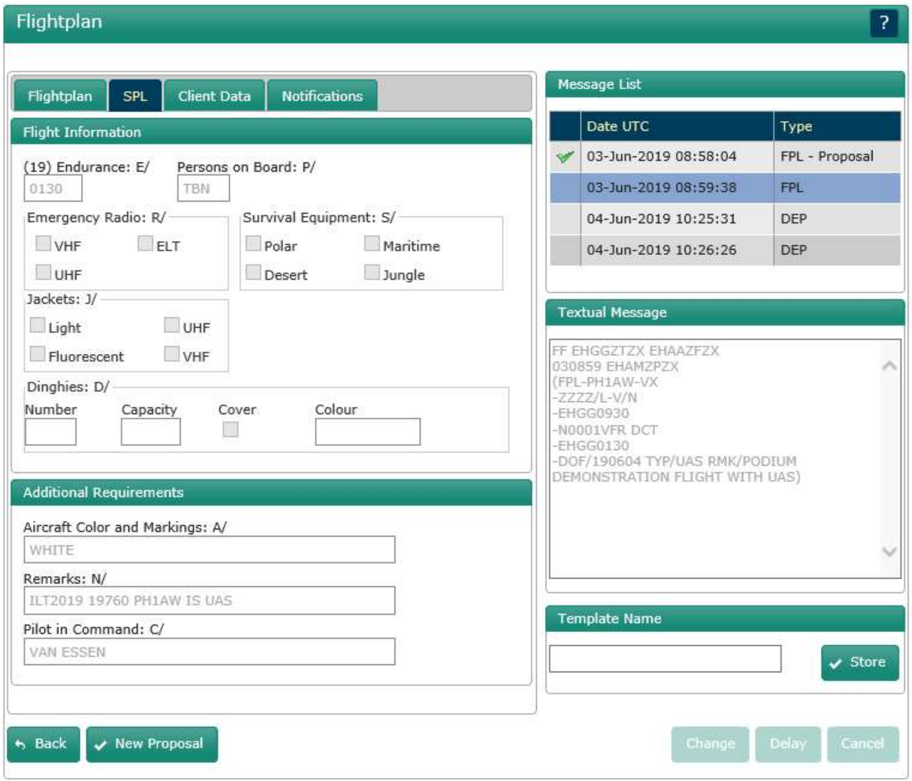
The key environment conditions for the PODIUM demonstration flights at NRTC and Eelde are:

- Nominal
- Flight rules: VLOS, BVLOS, VFR, IFR
- Environments: suburban, rural environment, within CTR.

Submitting ATC flight plan

In accordance with AIP the Netherlands ENR1.10 it is mandatory to issue an ICAO flight plan for any flight or portion thereof to be provided with air traffic control service. The ATC flight plan was submitted with the use of telephone assistance as it was not clear on how to fill-in the forms from the perspective of a drone flight. The required fields did not match the operational flight plan as currently defined by the U-space service provider. The figures below show how it should be filled-in.





<u>Tracking</u>

By equipping drones with light-weight transponders it proved to be possible to track their position. Although the availability performance of these transponders should be improved (see above), the situational awareness of ATC, and hence safety, improved by the ability to locate a drone's position. Furthermore, by using such trackers they may enable interoperability with other aerodrome or controlled airspace users (manned aviation) without the need to install additional equipment as would be required for other tracking options such as FLARM or LTE (mobile sim card) technologies. However, regulations currently do not allow small drones to be equipped by (non-certified) light-weight and low-power transponders, and there are no minimum standards for these.

<u>Priority</u>

The flight demonstration at NRTC comprised of the U-space system instructing two agricultural drones to give way to drone of a higher priority. The concept of 'giving way' is not unknown to manned aviation: ATC can vector aircraft away from an aircraft of higher priority or, if there is no ATC, the Rules of the Air determine which aircraft has the right of way depending on the geometry of the engagement and the types of aircraft involved. For drones, it is generally accepted that, e.g. a drone delivering a medical service should always have priority over a drone that is flying for leisure. However, there is no consensus yet about the number of priority levels, which level of priority should be assigned to which type of mission and how and by whom that's determined.

The conclusions for pre-flight preparations are:

Conclusion #10: The format for submitting an ICAO flight plan for the purpose of a drone flight by internet is not clear and does not matches the operational flight plan as currently defined by the U-space service provider.

The conclusions for flight execution are:

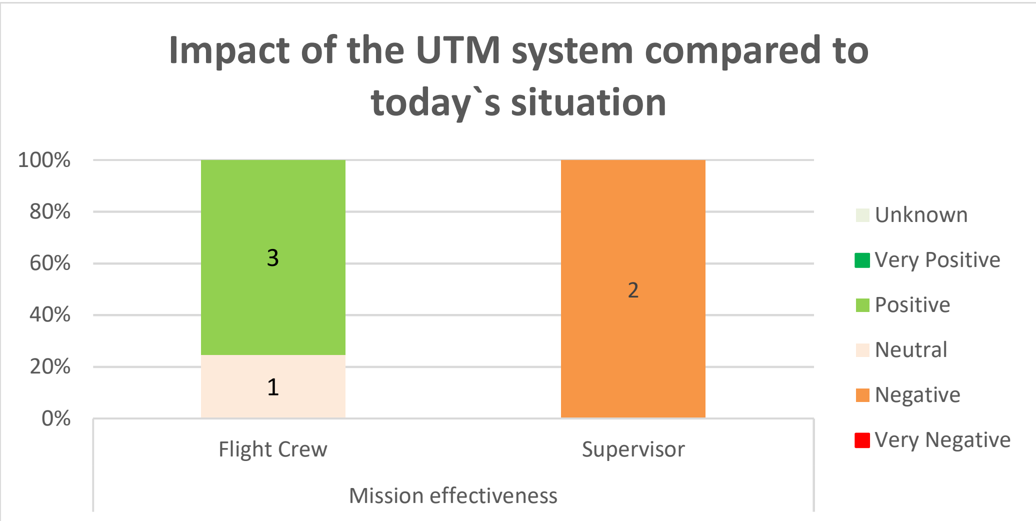
Conclusion #11: Regulations currently do not allow small drones to be equipped by light-weight low-power transponders (as these, by design, do not comply with all certification standards, i.e. minimum output power), and there are no minimum standards for these light-weight low-power transponders.

Conclusion #12: There is currently no rule-based scheme to determine the level of priority of a mission applicable to all U-space systems.

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

The aim of this objective is to assess the benefits of the U-space services that were used during the demonstrations, notably cost effectiveness in terms of time, effort and costs, and capacity increase in terms of the potential for enabling more simultaneous flights.

As a demonstrator project, PODIUM was not equipped to measure and quantify cost effectiveness and capacity increase, but could only base these on the expert judgment of the crews and supervisors. For this, the questionnaires of the crews and supervisors yielded the following results:



The ratings for Mission Effectiveness show that most flight crews gave a positive response, while the supervisors were negative.

The crews were positive because they saw as major advantage the possibility to prepare and request permission for their operations well in advance of the actual flight. The increased situational awareness was also assessed as major advantage; however this is related to safety objectives and not to cost efficiency or capacity. The crews believe that this will lead to an increased operational efficiency, even though at this moment the treatment of flight requests was not assessed as positive by the supervisors. The flight crews suggested that U-space systems may lead to cost efficiencies and increased capacity because:

- All drone operations would be in one system, and

- Enhanced mission planning possibilities.

The main reason for the negative scores by the supervisors is the timeliness of information provided by the U-space system, which was considered to be too slow. This would have a negative impact on the capacity of operations. Another reason for their negative score is that the process for treating the operations was found to be too cumbersome. The other points the supervisors indicated having an impact on cost effectiveness and increased capacity are:

- Possibility in future to automate flight permissions, and
- Relatively easy transition from current operations.

The conclusions are:

Conclusion #13: The current technology status of the U-space system is more of benefit to operators and flight crews than to supervisors. The supervisor role would benefit from more (or completely made redundant by) automation, especially outside of manned controlled aerodrome environments.

A.3.3 Unexpected Behaviours/Results

Unexpected event: HEMS scramble

During the visitor's day at Eelde, a HEMS helicopter was scrambled just after ATC had approved the drone flight. Thereupon ATC called the drone crew by R/T and cancelled the approval because of the HEMS, but did not receive a response right away. ATC observed visually and on the U-space display that the drone made a 180 turn immediately after take-off and returned for landing, assumedly for a full stop. Thereupon the drone crew responded to ATC's R/T call.

At the drone site, the ATC call was heard but there was nobody near the radio to respond. The drone control was being transferred from the external pilot to the BVLOS pilot. The pilots heard the radio call, immediately cancelled the transfer and decided to return for landing. Finally the crew responded to ATC's R/T call.

Observations:

- The pilots were not in direct R/T contact with ATC because the controls did not allow them to perform this task while flying.
- The crew executed a manoeuvre without first communicating this with ATC.
- The lost-communications procedures for the drone foresaw in a landing within 2 minutes at the furthest route point; this is within the required response time for the HEMS.

Observation #04: The pilot flying of the drone shall be in direct contact with ATC. Observation #05: All manoeuvres shall be communicated with ATC before execution. Observation #06: Lost link procedures shall be tuned to the local normal and non-normal procedures.

Unexpected behaviour: transponder outages

While the MTD's transponder seemed to operate flawlessly during the flights at NRTC, it did not during all flights at Eelde. Replacing the antenna on the drone gave some improvement, but did not completely solve the issue. Possible causes are interference with the other equipment on board the MTD, and the need to reacquire satellites after (steep) turns.

Observation #07: There shall be performance requirements for all required equipment on board the drone.

Unexpected behaviour: mobile telephone as back-up

It is generally regarded as a major advantage of drone operations, that anyone who wants to contact the pilot can simply contact him by his mobile telephone. On the first preparation day at NRTC it appeared that it was not possible to inform the pilots by the U-space system that their drones had to clear the area for the high priority drone as there was no in-flight communication mean. Thereupon the supervisor decided to contact the pilots by telephone, but in vain: one pilot could not hear his telephone ringing because he was wearing a headset, the other pilot did hear his telephone ringing but ignored it because he was piloting his drone.

Observation #08: Whenever a pilot provides a telephone number for a flight, he shall be able to answer a call on that specific number and do so.

A.3.4 Confidence in Results of Exercise 1

1. Limitations of Exercise Results

U-space as add-on to normal operations

The flight demonstrations demonstrated the services and capabilities of U-space, but for current regulatory and safety reasons did not rely on U-space: all flights were planned and performed as if there were no U-space, and additionally also planned and performed by using U-space. Hence the crews, supervisors and ATCO had to perform their normal tasks, and on top of that also perform the same task by using U-space. As a consequence, their workload could only be higher than without U-space. This has biased the assessment.

Other airspace users

The flight demonstrations at NRTC were performed in restricted airspace that was activated by NOTAM, the flight demonstrations at Eelde airport were performed while the airport was PPR for other airspace users, and the airport authorities only denied other airspace users the access to the airport and CTR. Hence no other airspace users were involved.

Pilot experience level

All crew members were experienced drone pilots, who were well trained in the procedures for the specific demonstration and had been trained in using the U-space system as needed because the flight demonstrations on the visitors days should be well-organised. Also the flight demonstrations had to be precisely orchestrated and minutely timed in order to obtain the desired conflicting engagement geometries; this can only be achieved by such experienced and trained crews. As a consequence, the assessments by the flight crews may not be representative for less experienced flight crews.

Supervisor

According to the Blueprint, U-space services should be provided by highly automated systems, including the processing of operational flight plans and de-conflicting pre-flight and in-flight. These tasks are not yet implemented in the system, and were hence performed by a human supervisor.

Assessing U-space through a system

It was emphasized during the filling-in of the questionnaires and during the de-briefing sessions that the assessment should focus on the U-Space services and principles, and not on the specific system of a U-Space service provider system. The respondents indicated that it was difficult to distinguish between the U-space services and the specific system that they had used. This is reflected in some of the interim conclusions. Nonetheless, the feedback that was given gave insight into which aspects are important to improve, such as the availability of a device enabling interaction with the U-space system while on location.

Lack of familiarity with the UTM system

The 'training/ familiarity' questionnaire offered to the participants in the beginning of the demo sessions indicated that they did not feel sufficiently "familiar" with the UTM system and hence were less "comfortable" using it, which might have influenced their performance.

2. Quality of Exercise Results

The 'exercise' consisted of providing a demonstration of the use of U-space; it was not the objective to perform any quantitative measurements. Yet NLR applied its protocols as if it were a flight test: each participant had 'flight test card' with a summary of what was expected of him, and all steps of the flight demonstrations were tested and evaluated, first each step individually, then all steps combined. As especially for the Eelde scenarios the number of interviewees was limited yet consisted of experts (well-trained drone pilots, air traffic controllers and supervisors), the questionnaire results should not be interpreted statistically, but should be treated as expert judgements.

This combination supports a high level of confidence in the results on how current U-space systems and technology can cope with unexpected situations both in a rural and ATC controlled airport environment.

3. Significance of Exercise Results

The scenarios for the flight demonstrations were taken from realistic applications: farmers inspecting their fields, an AED drone on an emergency mission, a BVLOS training flight. Also these missions were flown in suitable environments: the farmers' missions in the rural area of NRTC, the BVLOS training mission at an airport.

All crews comprised of experienced pilots, as would be expected of flights with a commercial objective.

All flights were approved by the competent authority, after the usual process of obtaining such approval, and by operators who had the appropriate privileges. Hence the demonstration flights are not a one-time event, but could be performed by any operator who has the appropriate privileges and follows the usual approval process.

A.3.5 Conclusions

1. Conclusions on concept clarification

The concept of U-space as a set of services was partially assessed as clear and acceptable. The concept of operations regarding flight plan submission and updating was assessed as clear and acceptable. However, the applied software showed limitations and the HMI was not assessed as clear and acceptable. An ICAO flight plan was required for flights at a civil controlled aerodrome. However, the format for submitting an ICAO flight plan for drone operations did not match the input for the operational flight plan as currently defined by the U-space service provider. Furthermore, in order to accommodate multiple interfering drone flights in an automated manner (without a human supervisor in the loop) a common rule based scheme to determine the level of priority of a mission is lacking.

2. Conclusions on technical feasibility and architecture

U-space provides a mean of managing drone traffic in a way that is not possible with today's ATM infrastructure. The technical feasibility of the pre-flight U-space services proved sufficiently mature to continue with tailoring it to the needs of the users. Due to a lack a direct mean of communication between the supervisor/ATC and the crew, the U-space interface alone did not suffice as sole means for conflict detection/alerting. Moreover the crew did not receive all safety related information, and was not informed about other drone operations in the vicinity and ATC and the supervisor could not track the drone in-flight at all times. However it is evaluated by the all actors that this is more related to the needed further development of the technical systems than with the overall architecture. Using a laptop is not practicable in the field, also because connectivity may not be ensured. Therefore mobile applications are considered as essential for in-flight services, such as dynamic geo-fencing and conflict detection, within the U-space architecture.

3. Conclusions on performance assessments

Based on the performed demonstrations and analysis, U-space performance assessments can be made on human performance and technical and safety matters. Regarding human performance, in these demonstrations the U-space services were used as an add-on to normal operations, and hence could only mean that the workload increased. It is assessed that the supervisor role, outside of manned controlled aerodrome environments, can only be pragmatically implemented if this would be performed by an automated system. In terms of technical matters the trackers performed intermittently; hence ATC was not aware of the drone's position at all times. Furthermore, drones equipped with multiple trackers revealed significant differences between the drone's position as measured by one tracker and the position as measured by the other. The flight demonstrations yielded that safety may be compromised by insufficient timeliness of the provided information, and the described technical issues. For all these issues, standards are lacking, especially for equipment, software and data of which failure reduces safety to an unacceptable level.

A.3.6 Recommendations and requirements

As the performed exercises focussed on demonstrating U-space services with the current state of technology these could not be classified as measurement trials. As a consequence, no quantitative requirements could be derived from these demonstrations. Nonetheless, the following recommendations are made which are considered to be needed before actual implementation:

- Ensure that the operational flight plan as currently defined by the U-space service provider can be used as an ICAO flight plan to ensure interoperability for drone operations at a civil controlled aerodrome
- Define and implement one unique rule-based scheme to determine the level of priority of a mission, and applies to all U-space systems
- Introduce a mean to enable a reliable direct communication between the supervisor/ATC and the crew during the flight considering mobile applications and mitigating their shortcomings
- Develop a regulatory framework enabling automated flight approvals for flights outside of manned controlled aerodrome environments

- Develop a protocol for coordination procedures (pilot-supervisor) and corresponding phraseology
- Develop standards for equipment, software and data of which failure reduces safety to an unacceptable level
- Assess the area of operations, (presumably those within manned controlled aerodrome environments) in which transponder based tracking eases interoperability the most and provide minimum standards for this type of trackers considering the drone characteristics including electrical magnetic susceptibility

A.3.7 References

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

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

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

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