EXPLORATORY RESEARCH

Second Validation Report

Deliverable ID:	D5.3
Dissemination Level:	PU
Project Acronym:	FACT
Grant:	894616
Call:	H2020-SESAR-2019-2
Topic:	Enabling Aviation Infrastructure: Innovation in CNS to enable Digitalised Operations
Consortium Coordinator:	HI SRO
Edition date:	08 December 2022
Edition:	00.01.01
Template Edition:	02.00.05

EUROPEAN PARTNERSHIP

Co-funded by the European Union

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Document History

Edition	Date	Status	Name / Beneficiary	Justification
00.00.01	15/08/2022		İlkay Orhan	
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00.00.02	02/09/2022		Ugur Turhan	
00.00.02	02/09/2022		Haluk Yapıcıoğlu	
00.00.03	05/09/2022		İlkay Orhan	
00.00.03	02/09/2022		Haluk Yapıcıoğlu	
00.00.04	08/09/2022		Mustafa Oğuz Diken	
00.00.04	12/09/2022		Ramazan Yeniçeri	
00.00.04	13/09/2022		İlkay Orhan	
00.00.04	13/09/2022		Haluk Yapıcıoğlu	
00.00.05	13/09/2022		Petr Casek	
00.00.06	14/09/2022		İlkay Orhan	
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00.00.06	15/09/2022		Klaus-Peter Sternemann	
00.00.06	15/09/2022		Ipek Ösken	
00.00.06	16/09/2022		Ramazan Yeniçeri	
00.00.07	17/09/2022		Haluk Yapıcıoğlu	
00.00.07	17/09/2022		İlkay Orhan	
00.00.07	19/09/2022		Mustafa Oğuz Diken	
00.00.08	20/09/2022		Haluk Yapıcıoğlu	
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FACT

FUTURE ALL AVIATION CNS TECHNOLOGY

This Second Validation Report is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 894616 under European Union's Horizon 2020 research and innovation programme.

Abstract

This document describes activities and results related to the preparation and execution of the project's operational demo that took place in July 2022 in Eskisehir, Turkey with the involvement of drones, a GA aircraft and a rotorcraft, and an airport within the controlled airspace. The operational demo represents a logical conclusion of the previous project's activities and was prepared according to the project's Final Concept of Operations (D2.3). Overall setup was prepared to reflect the functional architecture defined in the project's deliverable D2.4 (Final Functional Architecture) and using the systems described in D3.4 (Final Technology Demonstrators). In addition, the results of the previous project's validation activities described in the First Validation Report (D5.2) were taken into account during preparation of the demo.

Within this document a detailed description of the final operational and technical setup including practical aspects and difficulties that were necessary to manage during the demo campaign are provided including needed deviations from the original validation plan (D5.1). The results obtained from the performed field tests are presented and discussed in detail.

This document should be read after D5.1 (Validation Plan) And D5.2 (First Validation Report) that the reader has all needed contextual information on the use cases and scenarios addressed by the project, experimental plan and the platforms that were used for the validation activities. In addition, the results provided in this document will be discussed together with other complementary project's results in the Validation Assessment Report (D5.4) which will also summarize the overall project's recommendations.

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1 Executive Summary

The primary goal of the project FACT is to evaluate the feasibility of a Performance-Based Integrated CNS (iCNS) concept, in order to support today's and tomorrow's air traffic challenges in the most cost-effective way without negatively affecting the overall operational safety. In particular, the project focuses on selected elements of iCNS concept exploring primarily a potential use of cellular networks and (4G and 5G) as a complement to the existing CNS technologies within ATM and U space environment, with a particular focus on GA and drones' operations.

This document describes activities and results related to the preparation and execution of the project's operational demo that took place in July 2022 in Eskisehir, Turkey. The operational demo represents a logical conclusion of the previous project's activities and was prepared according to the project's Final Concept of Operations (D2.3). Overall setup was prepared to reflect the functional architecture defined in the project's deliverable D2.4 (Final Functional Architecture) and using the systems described in D3.4 (Final Technology Demonstrators). In addition, the results of the previous project's validation activities described in the First Validation Report (D5.2) were taken into account during preparation of the demo.

Within this document a detailed description of the final operational and technical setup including practical aspects and difficulties that were necessary to manage during the demo campaign is provided including necessary deviations from the original validation plan (D5.1). The results obtained from the performed field tests are presented and discussed in detail. There are two main blocks of results:

- Technical results focused on the performance and other characteristics of the cellular network used during the demo as well as on the behaviour of the experimental CNS systems.
- Operational results based on the feedback from air traffic controllers, GA and rotorcraft pilots and drone's operators primarily focused on the overall situation awareness and operational procedures.

This document should be read after D5.1 (Validation Plan) And D5.2 (First Validation Report) that the reader has all needed contextual information on the use cases and scenarios addressed by the project, experimental plan and the platforms that will be used for the validation activities. In addition, the results provided in this document will be discussed together with other complementary project's results in the Validation Assessment Report D5.4 which will also summarize the overall project's recommendations.

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2 Introduction

2.1 Purpose and Scope of this Document

This document is the second validation activity report of the FACT project. It is developed within WP5, Task T5.3. Detailed validation objectives and the work plan for final validation exercises are included in this delivery.

Scenarios, measurements and a timeline were created based on the Validation Plan (5.1), refined and modified as necessary before the actual flights were realized.

For these exercises, operational performance was tested using LTE network technologies.

The relationships between project tasks can be summarized as in Figure 1 below.

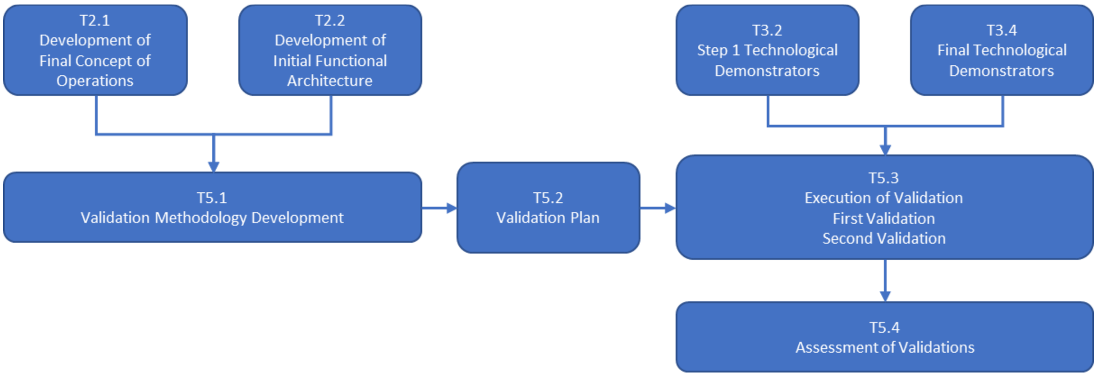

Figure 1. Relationship among T5.3 Validation Plan and other technical tasks of the project

This report relies on a number of other activities undertaken as a part of the project's scope. The document, in particular, uses the preliminary results of the first validation activities (T5.3) to refine planning for related objectives, scenarios, validation techniques, risk management plans, and projected outcomes.

2.2 Deliverable Structure

Section 2 of this document begins with an introduction and explanation of the document's objective. This section also includes a glossary of terms and acronyms used throughout the document.

The third section describes the actual validation activities performed on the field as a whole. In this section, all activities performed by Honeywell, ITU, ESTU and Sarp Air are explained in detail.

Honeywell evaluated the design of the experimental CNS device, the robustness of the hardware and mechanical solutions (for GA/rotorcraft and drones), the telemetry processing and recording features, the communication over the public LTE network, and the implementation of ground (U-space driven) services. ITU provided information about the drone and operation setup, and shared the results of the second validation studies. ESTU described the features and capabilities of the validation platform with a specific focus on experimental setups on fixed wing aircraft and the experimental setup on air traffic control tower. Following the successful execution of flight scenarios, obtained results are evaluated from ATC, pilots and safety point of view.

Execution of actual flight tests required an immense amount of work before aircraft were ready to take off. To this end, all the activities and work performed by the consortium members before their arrival to Eskisehir were detailed in Section 4. Then, explanations regarding the actual flight tests (pre-execution and execution) are provided in Section 5.

The risk management plan is an important aspect of any validation process, especially in the aviation industry. Section 6 is devoted to risk management assessments of verification activities in this context. A comprehensive risk management including input from the partners of the project consortium, the risk mitigation measures envisaged is presented. The document ends with a list of references and an appendix section.

All the results obtained during the field tests are explained in detail and important insights are provided in Section 7.

As very well known, the first and most important issue with any flying aircraft is the operational safety. In the aviation sector, each and every device that is going to be installed on an aircraft has to go through rigorous tests in order for them to be used. Since the experimental CNS device that is being developed within the scope of the project did not pass through these tests, it might pose potential risks with regard to the flight safety. Since ESTU Hasan Polatkan International airport is open to commercial and training flights, getting the required permissions was especially important before the actual tests began. For this purpose, ESTU team started communicating with the Directorate General of Civil Aviation, General Directorate of State Airports Authority, and Information and Communication Technologies Authority as early as January 2022 and received all the necessary permissions before the actual flight tests will be realized. All documents pertinent to these processes are provided as appendix at the end of the document.

2.3 Acronyms and Terminology

Acronyms and the terminology used throughout the report can be summarized as shown in Table 1.

Table 1. List of Acronyms Used in the Report

Term	Definition
ABIL	AirScale Baseband Extension Sub-Module
ADS-B	Automatic Dependent Surveillance-Broadcast
AFIS	Aerodrome Flight Information Service
AGL	Above Ground Level
AIP	Aeronautical Information Publication
AMSL	Above Mean Sea Level
AOE	Eskişehir Hasan Polatkan Airport
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
AUSF	Authentication Server Function
Base-S	Baseline Scenario
CIoT	Cellular IoT

CIP	Commercially Important Person
CIS	Common Information Sharing service
CNS	Communications, Navigation and Surveillance Systems
DL	Download
DME	Distance-Measuring Equipment
ECL	Emitter-Coupled Logic
EIRP	Effective Isotropically Radiated Power
eNB	Evolved Node
ESTU	Eskisehir Technical University
FACT	Future All Aviation CNS Technology
FMC	Flight Control Computer
GA	General Aviation
GE	Gigabit Ethernet
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HW	Hardware
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
iCNS	Integrated Communications, Navigation and Surveillance
ILS	Instrument Landing System
ITU	Istanbul Technical University
ITU ARC	Istanbul Technical University Aerospace Research Centre
LoRaWAN	Long Range Wide Area Network
LOS	Line-of-Sight
LPWA	Low-Power Wide Area
LTBY	Hasan Polatkan International Airport
LTE	Long Term Evolution
MCL	Maximum Coupling Loss
MME	Mobility Management Entity
MQTT	Message Queuing Telemetry Transport
NB-IoT	Narrowband Internet of Things
NF	Network functions
NG-RAN	Next Generation Radio Access Network
NLOS	Non-Line-of-Sight
NM	Nautical Mile
NNS	Non-Nominal Scenario
PGW	Packet Data Network Gateway
RAN	Radio Access Network
RC	Radio Controlled
RF	Radio Frequency
RRC	Radio Resource Control
RRH	Remote Radio Heads
RSRP	Reference Signal Received Power
RSSI	Received Signal Strength Indicator
RTK	Real-Time Kinematic
SCEF	Service Capability Exposure Function
SD	Secure Digital

SDR	Software Defined Radio
SESAR	Single European Sky ATM Research (the programme which defines the Research and Development activities and Projects within Europe)
SFC	Service Function Chaining
SGW	Serving Gateway
SNR	Signal-to-Noise Ratio
TDM	Time-Division Multiplexed
THY	Turkish Airlines
TX	Transmit
UAT	User Acceptance Testing
UAV	Unmanned Aerial Vehicles
UDM	Unified Data Management
UDR	Unified Data Repository (not shown in the figure above)
UE	User Equipment
UL	Upload/
VFR	Visual Flight Rules
UPF	User Plane Function
URLLC	Ultra-Reliable Low Latency Communication
USSP	U-Space Service Providers
VIP	Very Important Person
VLAN	Virtual Local Area Network
VOR	VHF Omni-directional Radio Range
WP	Work Package

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3 Validation Process

3.1 Introduction

Twelve scenarios were developed within the scope of D5.2, and ESTU run these scenarios with expert air traffic controllers and aerodrome controllers in a 3D real-time aerodrome control simulator during the first validation campaign. As a result of the studies on the scenarios in the project meetings considering limitations, the number of scenarios was reduced to five, and planning was made according to these five scenarios during the implementation phase. In the first phase of the validation, Honeywell also conducted studies on the communication of the developed CNS device over the public LTE network, positioning report generation function, trajectory report generation function, communication with flight control computer of drone. ITU has completed its studies on C2 Link Performance of the drone, trajectory tracking performance of the drone, geofencing/geocaging performance of the drone and Urgent landing performance of the drone. ESTU provided operational airport, airspace and workshop environment within the high-level harmony of all partners involved in the validation trials.

3.2 Validation Environment

By better monitoring and managing air traffic, including unmanned systems in various categories and cost-effective integrated solutions, the FACT goals will assist the ICAO Global Plans and Applications to promote general aviation safety and efficiency. The ESTU aerodrome control simulation environment was used to develop and test the flight scenarios before being applied to the actual air traffic environment at Hasan Polatkan International Airport (LTBY) and its controlled airspace. The general and commercial aviation traffic density at ESTU LTBY is moderate, and the airport uses traditional CNS technology. In addition to running its own international airport (LTBY-Hasan Polatkan Airport), ESTU also maintains a tower control facility with air traffic controllers from DHMI that offers air traffic services to commercial and training flight operations.

Flight operations are handled by flight training, aircraft maintenance and airport staff members and academics who are full-time employees of ESTU. ESTU has its own international airport. ESTU manages its own aircraft fleet and conducts ICAO and EASA-compliant aircraft maintenance procedures. The DHMI exclusively places controllers at the ESTU facilities to provide the aerodrome control service.

The ESTU Hasan Polatkan International Airport and its airspace, as well as the campus area was served as the actual testing environment for FACT validation research activities. The airport's IATA code is AOE, and its ICAO code is LYBY. The airport is utilized mostly for general aviation and training flights, as well as commercial flights from Brussels, Lion, and Mecca flights conducted on a charter basis by Turkish Airlines, Pegasus, TUIFly, Tailwing, and Corendon Airlines. The aerial photograph of ESTU Hasan Polatkan International Airport, the university and the areas close to the airport are shown in Figure 2

Figure 2 LTBY-Hasan Polatkan Airport

A ground control station point 10+ km north of the Hasan Polatkan Airport has been chosen for the execution of the tasks assigned to the drones in FACT validation flights as shown in Figure 3. A rectangular geocage zone has been defined for drones to keep the safety at the highest level during the validation flights. The field equipment of ITU-ARC, which meets all logistics needs, has been installed at the designated ground control station point. Clear LOS is provided between the drones and the ground station throughout the flights. All drone flights took place at a ceiling altitude of 120 m AGL.

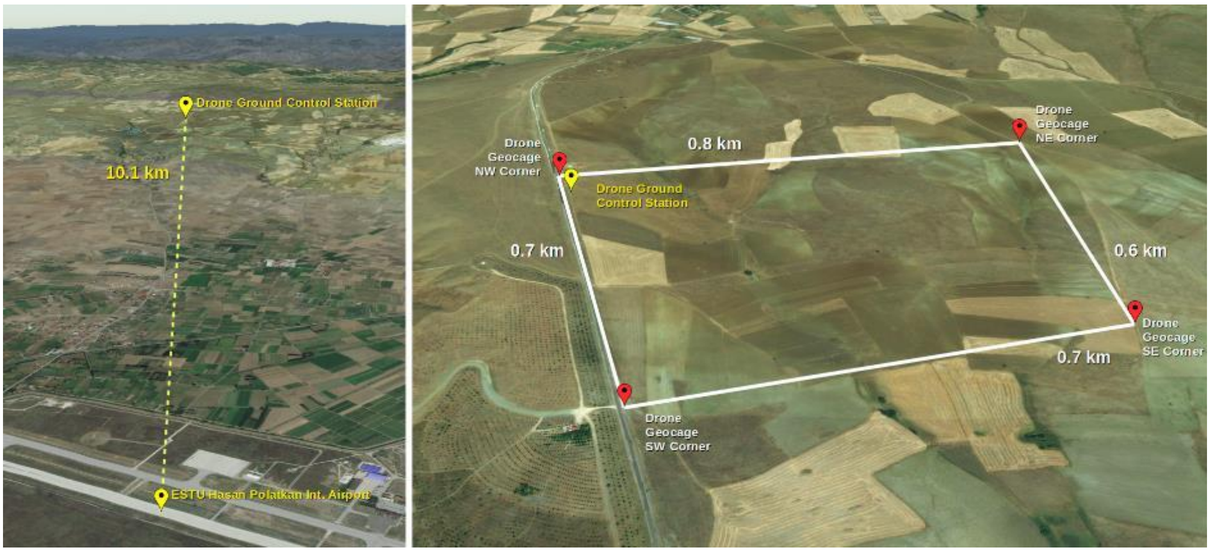


Figure 3 Ground Control Station and the Geocage

3.3 Validation Platforms

3.3.1 ESTU

ESTU contributed first and second validation studies with its 3D aerodrome control simulator, C-172 airplane, airport and aircraft maintenance hangar as described in detail at D5.1 and D5.2. During the final validations ESTU provided one C-172 and operational support such as pilots and aircraft maintenance technicians in addition to the airport, hangar and ATC tower facilities. The Cessna 172, the worlds' most produced trainer aircraft, is therefore the aircraft used in general aviation operations. For this reason, it was preferred in project scenarios. Cessna-172 with TC-SHN tail number used in ground tests of the developed CNC device is shown in Figure 4.

Figure 4 ESTU flight training GA airplane Cessna 172.

3.3.2 Sarp Air

Sarp Air participated in the project validation activities with Sikorsky S76 B model helicopter in addition to pilots and technicians. Preparation for the equipment installation and ground tests were performed at the hangar, Sarp Heliport, Eskisehir just prior to the flight tests.

Figure 5. Sarp Air Hangar Overview and Sikorsky S76 B

3.3.3 ITU

ITU participated in FACT validation activities with a mobile ground control station trailer, towing pickup, 2 main and 1 spare drone weighing 12 kg excluding payload, C2 data links, electric generator and uninterrupted power supply, ground station computers and auxiliary field equipment. ITU platforms and field test equipment is shown in Figure 6.

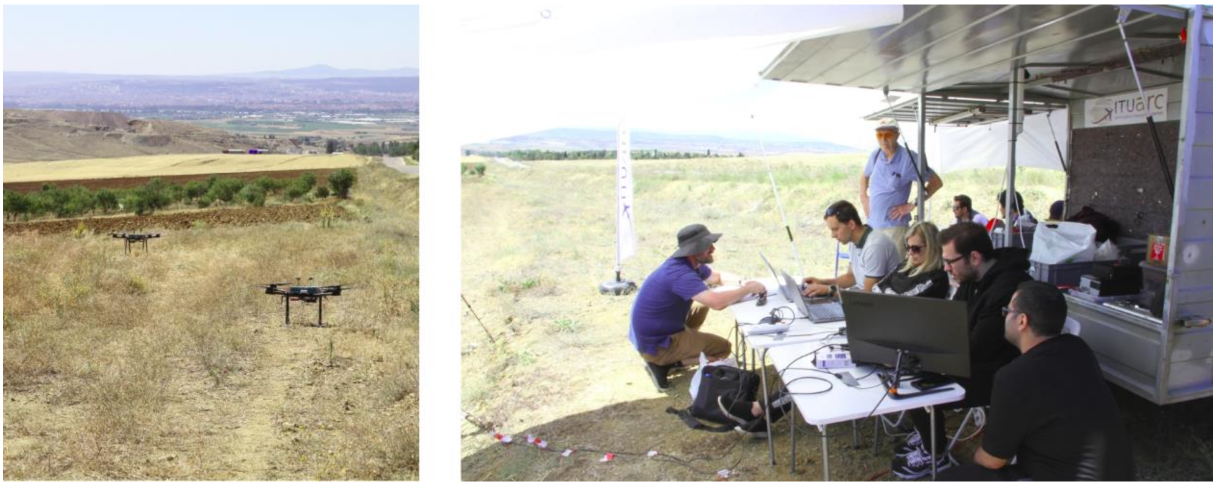


Figure 6. ITU platforms and field test equipment.

The drones participating in the FACT project have been named FACTOR and technical specifications are presented below in Table 2. The drones are loaded with a payload platform that brings together the Experimental CNS device provided by Honeywell, the GNSS receiver of this device, two 4G/LTE devices that provide communication, the payload battery, and the ADS-B out device. The approximate weight of this load is 1 kg.

Table 2. Technical specifications of FACT validation drone.

Technical Specifications 1 Platform	
Dimensions	1300×1300 ×700 mm (L × W × H)
Diagonal Wheelbase	118 cm
Maximum Altitude	500 m AGL
Endurance with Payload	25 min
Max Cruise Speed	36 km/h
Maximum Take-off Weight	14 kg
Max Operation Range	7.5 km

3.4 Deviations from Validation Plan

Within the project execution, it was necessary to adopt the following deviations from the validation plan described in D5.1.

Table 3: Deviations from Validation Plan (D5.1).

Reduction of validation scenarios for operational demo from 12 explored within first validation phase to 5	
Justification	It was result of a rationalization after analysis of first validation phase and also a way to facilitate risks mitigation during real flights. In any case the reduction was made with the strict requirements that it does not affect technical evaluations of network performance nor research questions explored through operational feedback of involved actors
Impact	There was no impact on technical measurements of network performance. Concerning collected operational feedback, it did not affect the scope/addressed questions, but slightly reduced variations of operational context for explored human tasks.
Measures took to minimize impact	No measures taken during demo – however, as all 12 scenarios were evaluated in simulator during first validation phase, they are considered as sufficiently covered for targeted maturity level.
Operational demo realized outside of airport and campus area	
Justification	For operational demo, the drone flight site was moved 10 km away from the airport as shown in Section 3.2 for safety priorities and risk mitigation.
Impact	No significant impact, as interaction with real airport traffic or infrastructure was not planned, and ATC played the same role in selected flight area as it was planned for original location.
Measures took to minimize impact	ATC handled the experimental flight in the new area in the same way as originally planned for airport/campus.
Use of public LTE network rather than originally planned dedicated 5G network	
Justification	This deviation was caused by global situation with suppliers of the chips during the last two years. Within the project it was first needed to agree and get approval of regulator for use of a dedicated spectrum. Unfortunately, once this step was successfully completed, Nokia's suppliers were not able to deliver ordered chips in time to use them for demo. The issues with purchasing HW components was faced multiple times during the project but in this case it was not possible to find a different solution.
Impact	This fact had primarily impact on technical evaluations as it is expected that a private (stand-alone) 5G network will be the most suitable business solution satisfying performance requirements of safety critical air traffic applications. As the project addressed both use of public network (Solution 1) and dedicated network (Solution 2), as the result of this deviation the focus of operational demo was moved from Solution 2 on Solution 1.
Measures took to minimize impact	In order to reduce impact of this deviation, the project team was looking for an alternative opportunity how to perform technical evaluations in dedicated

	5G network. Beyond testing in Nokia Lab in Stuttgart, additional (originally unplanned) experimental measurements were agreed with Technical University n Brno (Czechia).

3.5 Limitation and Difficulties

The main limiting factor was the Covid-19 situation. Project partners could not really work face to face before the validation studies. On the other hand, when validation partners met together during the real test validation, this limitation turned into harmony in the teamwork collaboration.

Another stressing factor was to get the official permissions for the validation studies in terms of airspace usage. The national authorities provided their approval before the planned validation activities which can be seen Appendix A.

One another unexpected factor was the airworthiness of the helicopter while approaching the validation actual flight days. It was not easy to find a standby helicopter to fly on the scheduled date as Sarp Air wouldn't manage to import the repaired part (HMU) install and test as required. At the end the required part imported, custom cleared, transferred to the hangar of SarpAir, installed, ground and flight tests were performed day before the schedule of project validation flights.

Another limitations in validation flights are the variable wind direction and high-speed wind gusts that started in the afternoon in the drone test area. Due to heavy wind conditions, which can reach up to 20 m/s blowing mostly from the north and northwest, it was decided to make the flights between early morning and noon. The high-velocity wind blowing in the drone test area is shown in Figure 7.

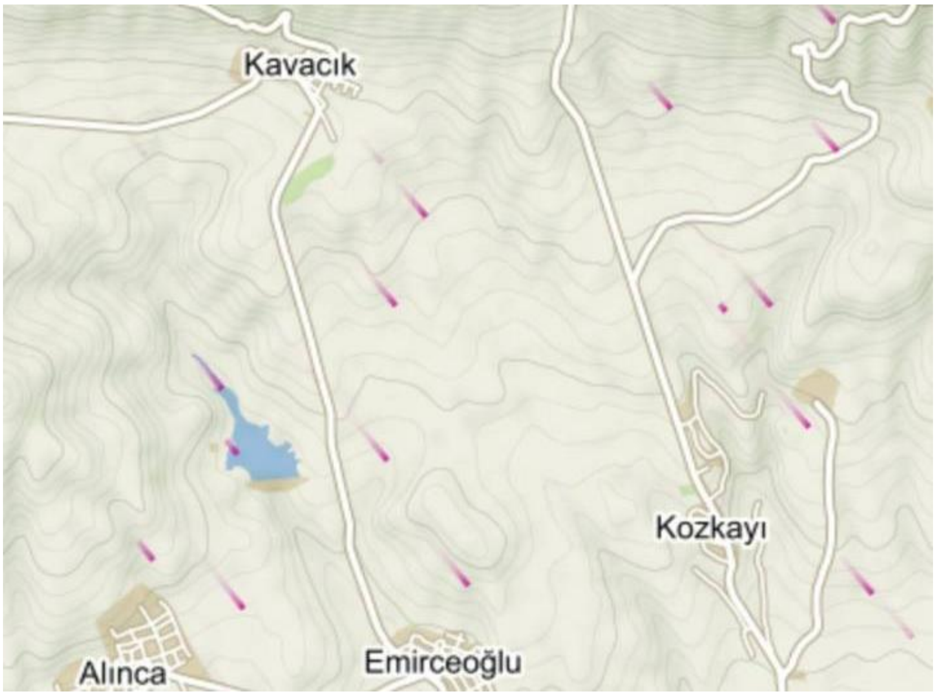


Figure 7. High speed wind gusts on drone test field.

4 Validation Preparations

4.1 Preparations of Scenarios

Validation scenarios were rediscussed by all partners again before the real validation execution. In the first validation studies, FACT project had 12 scenarios for the simulations. After the simulations and some considerations such as complexity of scenarios, partners involvement with the required 5G equipment and safety related risk analysis, consortium decided to run 5 scenarios.

Reducing number of scenarios from 12 to 5 increased understandability and adapting the vertical separations increase the flight safety. Separating fixed wing and rotary wing scenarios from each other were also very supportive decisions considering the risk management.

The executed version of scenarios and their breakdown and flight test cards are listed in Appendix B.

In the previous plan, drone flights would take place next to the northern border of the ESTU campus. Before the scenario demos, the drone flight site was moved 10 km away from the airport as shown in Section 3.2 for safety priorities and risk mitigation. For the flown scenarios, the corner points of the flight areas, intersection areas, flight routes, escape routes, geocage corner points were re-determined by conducting a field study in Eskisehir. For all scenarios, the drone flight area, routes and related scenario information are presented below subsections.

4.1.1 Scenario 1

In the first scenario, a GA aircraft enters the UTM-controlled drone flight area in the uncontrolled airspace. UTM's response to this entrance is to move the drone away from the aircraft with a geocage definition. The drone operator plans a new route according to the defined geocage, gets approval from UTM and continues the flight in accordance with the approved new route as illustrated in Figure 8.

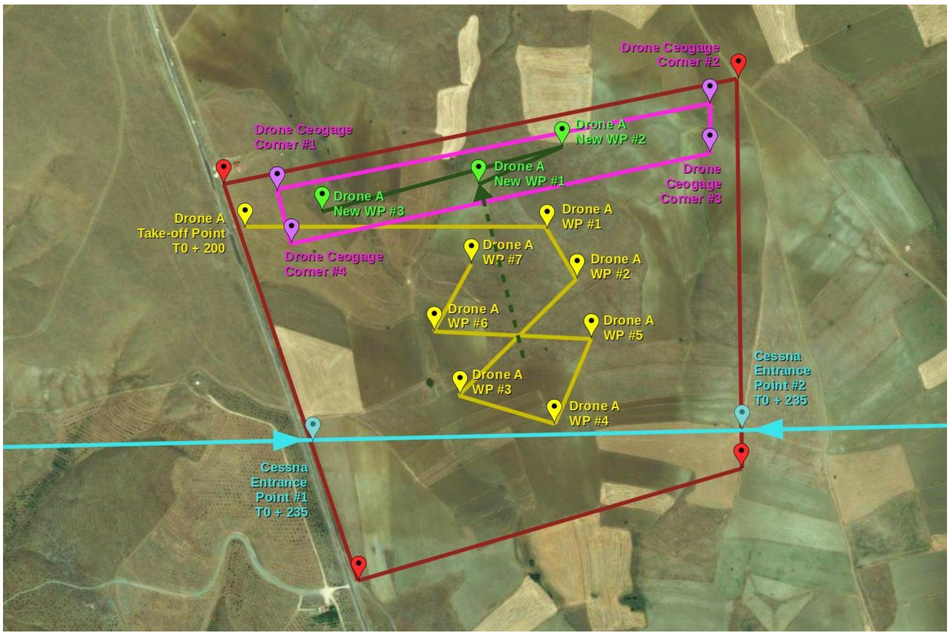


Figure 8. Corner points in drone flight area for Scenario 1

4.1.2 Scenario 2

In the second scenario, the drone under the surveillance of UTM goes out of the flight area allocated to it and violates the route of the GA aircraft as shown in Figure 10Figure 9. In response, UTM sends an emergency landing command to the drone. Meanwhile, GA informs the pilot. The drone makes the landing and the issue is cleared.

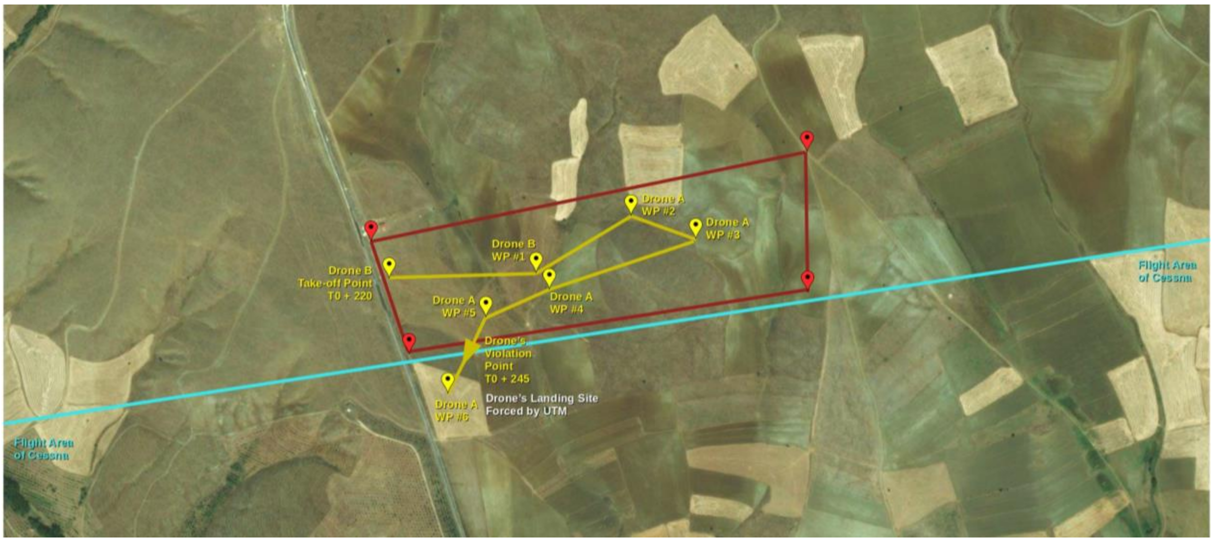


Figure 9. Corner points in drone flight area for Scenario 2

4.1.3 Scenario 3

The third scenario is performed by two drones sharing a common drone flight field. One of the drones begins to deviate from its UTM-approved route. After the UTM senses this deviation, the other drone operator proposes a new route within the identified acute geocage. The approved new plan is flown by the drone in cooperation as given in Figure 10.

Figure 10. Corner points in drone flight area for Scenario 3

4.1.4 Scenario 4

In the Scenario 4, ATC takes its place in the loop. The flight site is now a controlled airspace. When a helicopter enters the reserved area of one of the two flying drones, the situation is noticed by the ATC. The UTM is warned by ATM. Then, the UTM defines a geocage for the drone and the ATC contacts and informs the relevant drone operator. The operator asks for the confirmation of the new route according to the defined geocage and continues the flight. The corner points in the drone flight area and the helicopter route for scenario 4 are shown in Figure 11.

Figure 11. Corner points in drone flight area for Scenario 4

4.1.5 Scenario 5

In the last scenario, a single drone makes an off-route entry to the helicopter flight area. ATC warns the helicopter pilot. The drone operator, on the other hand, noticing the situation thanks to the situational awareness software, pulls the drone back to the flight area. Figure 12 depicts the drone flying area's corner locations as well as the helicopter path for Scenario 5.

Figure 12. Corner points in drone flight area for Scenario 5

4.2 Preparations by Honeywell

4.2.1 Hardware Finalization

Experimental CNS units were designed to satisfy multiple requirements from hardware point of view – low weight, low battery consumption, simple integration to Flight Control Computer of drone and easy access to components for manipulation.

Experimental CNS device was built on Raspberry Pi processor and the Quectel RM500Q was selected from the potential modem candidates per requirements described in the D5.2 First Validation Report. Quectel RM500Q contains four integrated antennas. These integrated antennas were tested in Brno (Czech Republic) before the official flight test and have been deemed suitable for installation on a drone. The reasons are evident – experimental CNS unit is installed outside directly in line-of-sight to mobile network base stations and the operational altitudes are significantly lower on drones which reduce requirements to antennas performance.

Quectel RM500Q integrated antennas are placed on the sides of the unit. The antennas are developed for the MIMO system. Each antenna has a special radiation pattern and is matched for certain LTE/5G band. Figure 13 show the position of integrated antennas as well as a detailed view of an integrated antenna.

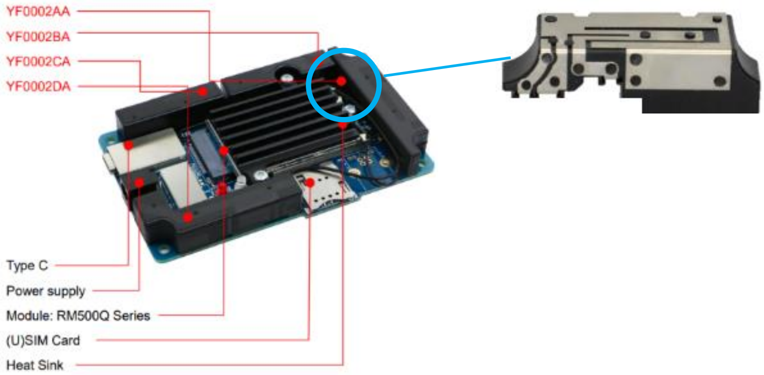


Figure 13. Integrated antennas location and integrated antenna in detailed view

Housing was designed for safety of device and suitable manipulation with it during installation on various vehicles. It allows also to connect external antenna for the case of using another type of antenna (non-integrated).

This option was used for aircraft version of experimental CNS unit where requirements for antennas are higher (antennas had to be installed inside the vehicle and the operational altitudes were at least four times higher). Figure 14 and Figure 15 show the version for use of integrated antennas and the version for connection of external antennas for the Housing for Quectel RM500Q, respectively.

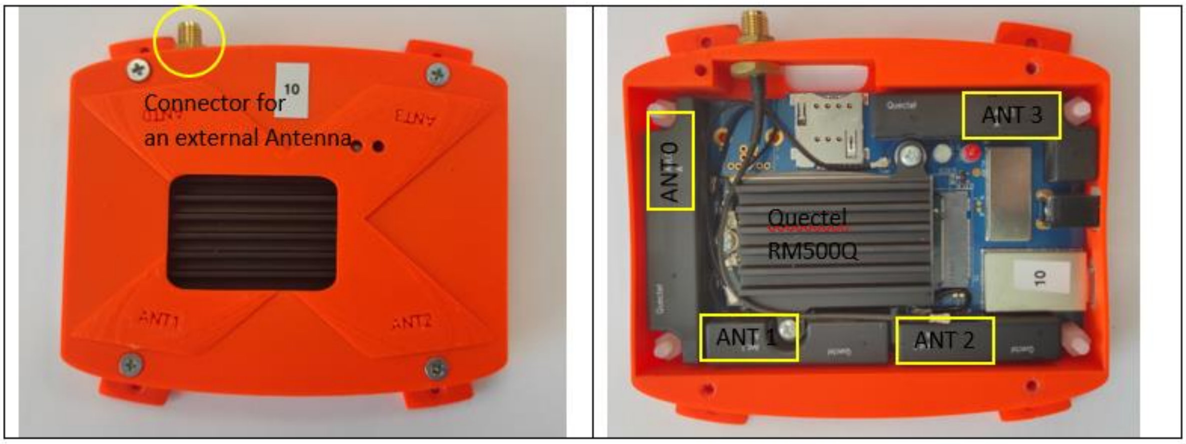


Figure 14. Housing for Quectel RM500Q – version for use of integrated antennas

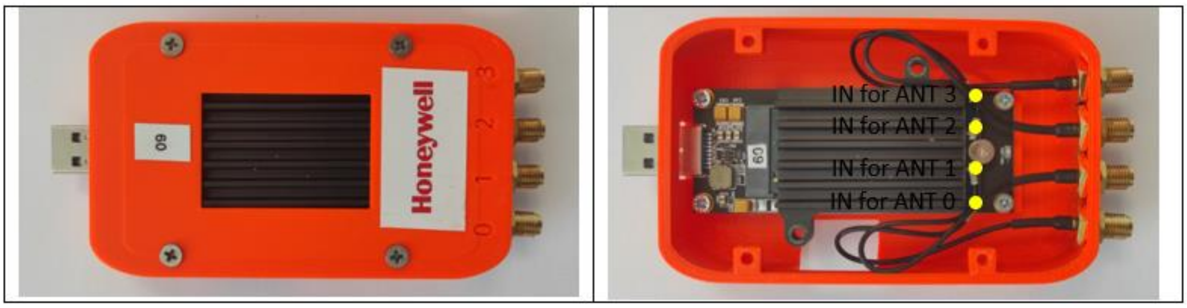
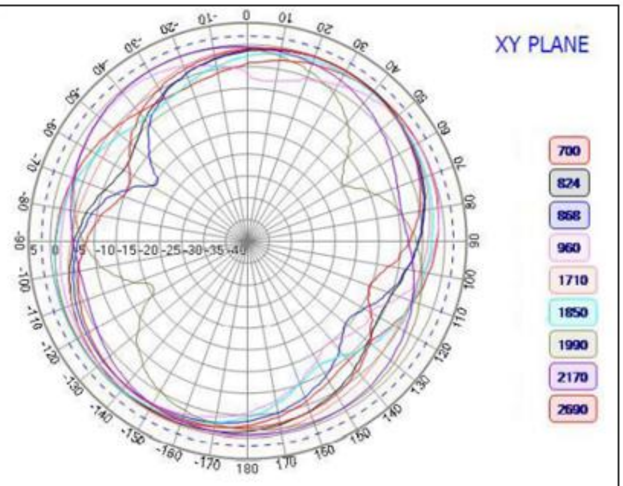


Figure 15. Housing for Quectel RM500Q – version for connection of external antennas

4.2.2 External Antennas

For operational restrictions, the external antennas could not be located on the fuselage of aircraft and helicopter. Thus, performance of selected antenna had to be strong enough to provide sufficient gain even inside the cabin. This limitation needs to be considered during results evaluation – results would be better in case of outside installation. Figure 16 shows the appearance and radiation pattern of an external antenna mounted on an aircraft and a helicopter.

	
Antenna view in 3D with XY plane	Radiation Pattern in XY plane

Technology	GSM/UMTS/LTE /Wi-Fi/GPS
Frequency bands	700/800/900/1700/1800/2100/2600 MHz 2.4/5 GHz 1574.42/1602 MHz
Gain	3 dBi (LTE), 2 dBi (WiFi), 0 dBi (GNSS)

Figure 16. Appearance and radiation pattern of external antenna installed on aircraft and helicopter

4.2.3 ADS-B In/Out

Approval for use of low power ADS-B Out transmitter was obtained for drone on second flight test day (Friday 22nd July). The uAvionix SkyEcho was chosen due to easy installation as standalone unit with own GPS and batteries. SkyEcho is certified under CAA Electronic Conspicuity[1] program for ADS-B Out equipage of general aviation aircraft and drones. Its transmission power is 20 W (whereas the lowest category of DO-260B certified transmitters requires power of 70 W). Due to specific certification valid

[1] https://www.caa.co.uk/general-aviation/aircraft-ownership-and-maintenance/electronic-conspicuity-devices/

only in some countries, an extra approval was required from local Air Traffic Control. uAvionix SkyEcho specification is shown in Figure 17.

	Specification	Value
	Input Power	5V USB 500mW
	Frequency	1090MHz ±1MHz
	Transmit Power	20W Nominal
	MTL 1090MHz	-88dBm
	1090 Dynamic Range	-87 to 0dBm
	Altimeter Range	-1000 to 60,000ft

Figure 17. uAvionix SkyEcho specification

4.2.4 HW and SW Integration on Drones

Experimental CNS devices with LTE modules were installed on ITU drones during first days of flight test week in Eskisehir. The mechanical attachment was relatively easy, the SW integration was more complicated due to establishment of direct communication between Flight Control Computer of drone and Experimental CNS device. Figure 18 displays an experimental CNS device with an LTE Modem housing mounted on a drone.

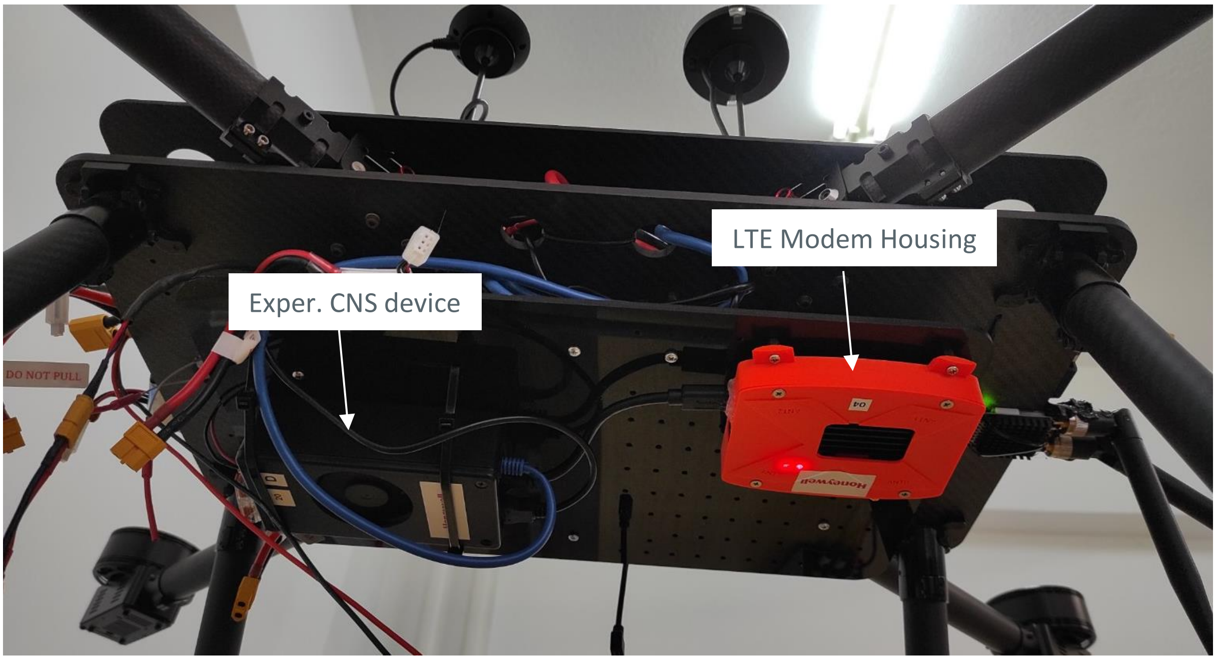


Figure 18. Experimental CNS device with LTE Modem housing installed on drone

Communication was realized via MQTT. ITU has deployed local MQTT broker which consumes specific data from Experimental CNS device (alerts, command to land). In other direction, experimental CNS device with own local MQTT broker was consuming position and attitude data from drone. Debugging and intercommunication tests were intensively carried out in the days before the flight test. ADS-B In/Out uAvionix SkyEcho installed on top of the drone is shown in Figure 19.

Figure 19. ADS-B In/Out uAvionix SkyEcho installed on top of the drone

4.2.5 HW and SW Integration in Aircraft and Helicopter

Experimental CNS device for installation to aircraft and helicopter was attached to carbon plate to enable easy installation of all required components (LTE module, power bank). This carbon plate was fixed on ground of vehicle. Tablet with situational awareness application was fixed on left side of cabin window. Antennas were installed behind the window to maximize signal reception. Figure 20 depicts a tablet and an experimental CNS device with an LTE module for aircraft/helicopter installation. The mounted experimental CNS device is shown in Figure 21.

Figure 20. Tablet and Experimental CNS device with LTE module for aircraft/helicopter installation

The omnidirectional MIMO antenna	Setup with CNS Device

Figure 21. Installation in Helicopter

4.2.6 On-site Evaluation

On-site evaluation before official flights involved:

- Test of mutual communication between Experimental CNS device installed on drone and Flight Control Computer of drone
- Test of physical integrity and robustness of installation on drone
- Functional test of standalone experimental CNS device installed in aircraft and helicopter
- Test of communication via CIS (MQTT broker running in MS Azure receiving and accessing information for all involved participants)
    - Accessibility of traffic information data for ATC
    - Accessibility of position reports for ground server
    - Accessibility of data for all onboard units
    - Accessibility of data for drones ground control station
- Functional test of situational awareness application for GA pilots
- Functional test of situational awareness application for demo operator (running locally on ground station).

4.3 Preparations by ITU

For the FACT validation flights, the following itemized preparations were carried out by ITU.

- The number of drones that are capable of participating in validation flights has been increased from 1 to 3. Drone performance test flights were carried out in Istanbul and Eskisehir. ITU-ARC's newly prepared drones are shown in Figure 22.

Figure 22. ITU-ARC's newly prepared drones.

- The currently used ground control station software has been upgraded to handle FACT messages and perform validation flights.
- The sample Experimental CNS device and 4G modem sent by Honeywell were prepared for desktop testing in the ITU-ARC avionics laboratory. By holding online meetings with Honeywell, the devices were enabled to work with the SIM cards of the local mobile operators in Turkey. In addition, the message transmission infrastructure (MQTT) was tested using synthetic FACT messages obtained with the simulated drone.
- SIM cards were purchased from alternative operators required for all Experimental CNS devices.

- Carrier carbon fibre plates have been added to the drones for the payload that Honeywell will place on the drones. Technical drawings shared with Honeywell. The carrier plates for Honeywell's Experimental CNS device and its peripherals are shown in Figure 23.

Figure 23. Carrier plates for Honeywell's Experimental CNS device and its peripherals.

- FACT drones were registered through the civil aviation authority's registration and flight permission portal. Pilots and operators of the drones are defined. Permission was requested from the civil aviation authority for the area adjacent to the ESTU campus, selected in the initial FACT validation scenarios, as the drone flight site.
- Local MQTT broker software running on the Flight Management Computers of the drones has been installed so that the Experimental CNS device can receive data from the drone and give commands.

4.4 Preparations by SARPAIR

During preparations, Sarp Air worked together with ESTU team. To this end, scenarios were simplified, as explained in Section 4.1. Durations of the flights were calculated and vertical and lateral separations were identified with regard to the risk management.

On the very last minute, tests needed to be flown out of the CTR of the airport. New area has been explored together with ESTU/ ITU and Sarp Air the day before the scheduled flight date.

Participated to all meetings for 5G purposes, areal determination, pilots' coordination for flight safety, simulator sessions.

4.5 Preparations by AOPA

Initial visits to Eskisehir in December 2021 and Stuttgart in March 2022 helped to better understand site capabilities and establish personal contact to ESTU and Nokia partners, respectively.

This helped to review and contribute details our test cases considering the given local restrictions.

4.6 Preparations by ESTU

ESTU was asked to conduct the required permission applications for the 5G band base station that Nokia would construct its infrastructure at the weekly partner meetings. ESTU organized the preparation of the necessary documents, evaluation meetings attended by Nokia Turkey, ITU and Sarp Air, and field analysis planning and exploration for 5G band usage and installation permission. In this process, detailed information about the importance of the project was given by being in constant communication with the Information Technologies and Communications Authority

Two meetings (on dates 15/03/2022 and 30/03/2022) were held in Eskişehir with the involvement of ITU, ESTU, Sarp Air, and Nokia-Turkey teams after Nokia provided information regarding the tools and equipment necessary for the application processes.

The application file was prepared with technical assistance from the Nokia Turkey team to cover the flying area in the best feasible way in terms of signal. In May 2022, the necessary approvals for the establishment and usage of private 5G network was received (Appendix A.1). However, due to the difficulties encountered in the procurement of devices necessary for the establishment of private 5G network faced by Nokia, FACT project team decided to proceed with the existing public 4G and LTE network available in the campus area of ESTU.

Figure 24 Developed ATC interface

During the ATC interface development phase, ESTU outsourced domain experts to create ATCO display. ATCO display was created on the Cesium JS online platform for better situational awareness for the operators and data interchange among to other operational stakeholders. The geocage and geofence lines on the MQTT may be seen in three dimensions from every angle thanks to the three-dimensional map given by Cesium JS, and the camera angle can be readily altered according to need, as shown in Figure 24. The developed ATC interface enables ATC personnel to easily observe any air vehicles (aircraft, helicopter, drones, etc) that actively share location and ID information within the designated airspace. As part of the development of the ATC Interface, the ESTU team visited the ITU team in Istanbul (on dates 2/6/2022), and the progress completed was evaluated.

The visual maps defining the scenarios were produced, and the coordinates and maps created on Google Earth were shared with the partners to help with the planning and evaluations for the scenarios, which were reduced to five in weekly meetings.

ESTU organized a series of meetings attended by the pilots of the Cessna 172 SP fixed-wing aircraft (Captain Özkan Yüksek) and the Sikorsky S76 B helicopter (Captain Mustafa Oğuz Diken). The developed scenarios and flight risks were evaluated in these meetings. In addition, the requirements for the risk’s mitigation were determined.

Meetings were held with the required ESTU authorities, information about the project was presented, and approvals were secured in order to carry out the flights in the scenarios using the Cessna-172, where the developed CNS device would be installed. The General Directorate of Civil Aviation was applied for the permission of the flights planned with Cessna-172 in the scenarios. Additional documents requested in the process were provided to the authority. The approval document for flights is included in Appendix A-2.

5 Validation Activities

5.1 Pre-execution

5.1.1 Scenario refinement

In the pre-execution phase of validation, some changes were made that were not at the core of the scenarios. It is possible to summarize these changes as the relocation of the drone operation field to a remote area from the airport. In accordance with the changing geometry of the drone flight area, the routes and geocage corner points have also changed. The GA aircraft and helicopter routes have also been updated according to the new region. Detailed information is presented in Section 4.1. The change was taken as a joint decision of the F2F meetings and the consortium members (Figure 25).

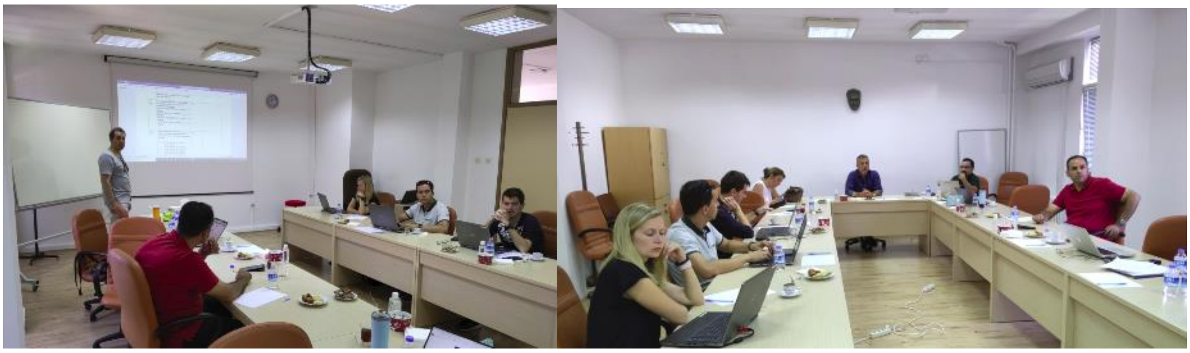


Figure 25. Pre-execution F2F meeting

5.1.2 Flight airspace selection and settling

The flight airspace was examined considering safety and technical capabilities. The test flight area in the scenarios was determined to be located at the border of Eskişehir Technical University Campus, nearly 1 km north of Eskişehir Hasan Polatkan Airport, depending on the area where the 5G base station will be built and covered, during routine weekly meetings with the partners. However, when it became clear that the requisite infrastructure could not be built within the project timeline despite acquiring the necessary permissions for 5G, it was decided to run the scenarios in the same location using 4G and LTE bands. One of the benefits of the location chosen for the scenarios was the availability of three separate mobile operators' base stations within a one-kilometre radius.

The administrative processes took longer than planned. Within the scope of the project, the ESTU team obtained the required permissions from the General Directorate of Civil Aviation for Cessna-172 flights before the scheduled flying day. Despite their application, the ITU team was unable to get permissions for drone flight for the planned flight zone. General Directorate of Civil Aviation is very keen on obeying the regulation stating that no drone flight is allowed within a 5 km radius of any airport. As a result, the ESTU, SARP Air, and Honeywell teams have selected a new flight/test region where ITU drones can be flown and all the flight scenarios were updated accordingly. FACT validation partners conducted reconnaissance flights to the northwest of the controlled airspace of the airport. Sarp Air conducted testing flights in the area. The photo of the new flight area selected for the scenario execution and drone flight is shown in Figure 26.

The flight airspace was examined considering safety and technical capabilities. Initial selection for the Drone airspace had to be changed since ITU application was not accepted by national civil aviation authority due to the proximity to the airport. Later, ITU and ESTU suggested to change airspace location for drone flights. FACT validation partners made discovery visits in the northwest of controlled airspace of aerodrome. ITU coordinated to have required permission with the local authorities for new airspace location such as Military air base and controllers.

Figure 26. The photo of the new flight area selected for the scenario execution and drone flight

5.1.3 Drone set up

Two days before the validation flights, as the ITU team, preparatory flights were carried out to check the health of the drones, batteries, data link, RC link, and ground control station software. The pre-execution drone flights and ground control station on site are shown in Figure 27.

Figure 27. Pre-execution drone flights and ground control station on site

5.1.4 Fixed and rotating wing set up

The experimental CNS device developed by Honeywell was installed on ESTU's Cessna 172 aircraft and SARP Air's Sikorsky S76 B helicopter (Figure 28. The device verification experiment was carried out on the apron in front of the aircraft maintenance hangar with the participation of partners ESTU, ESTU aircraft maintenance technicians and Honeywell. In this process, it was verified whether the data flow between the developed CNS device and the ground station, and whether there was an unusual situation caused by interference in the Cessna aircraft cockpit screens.

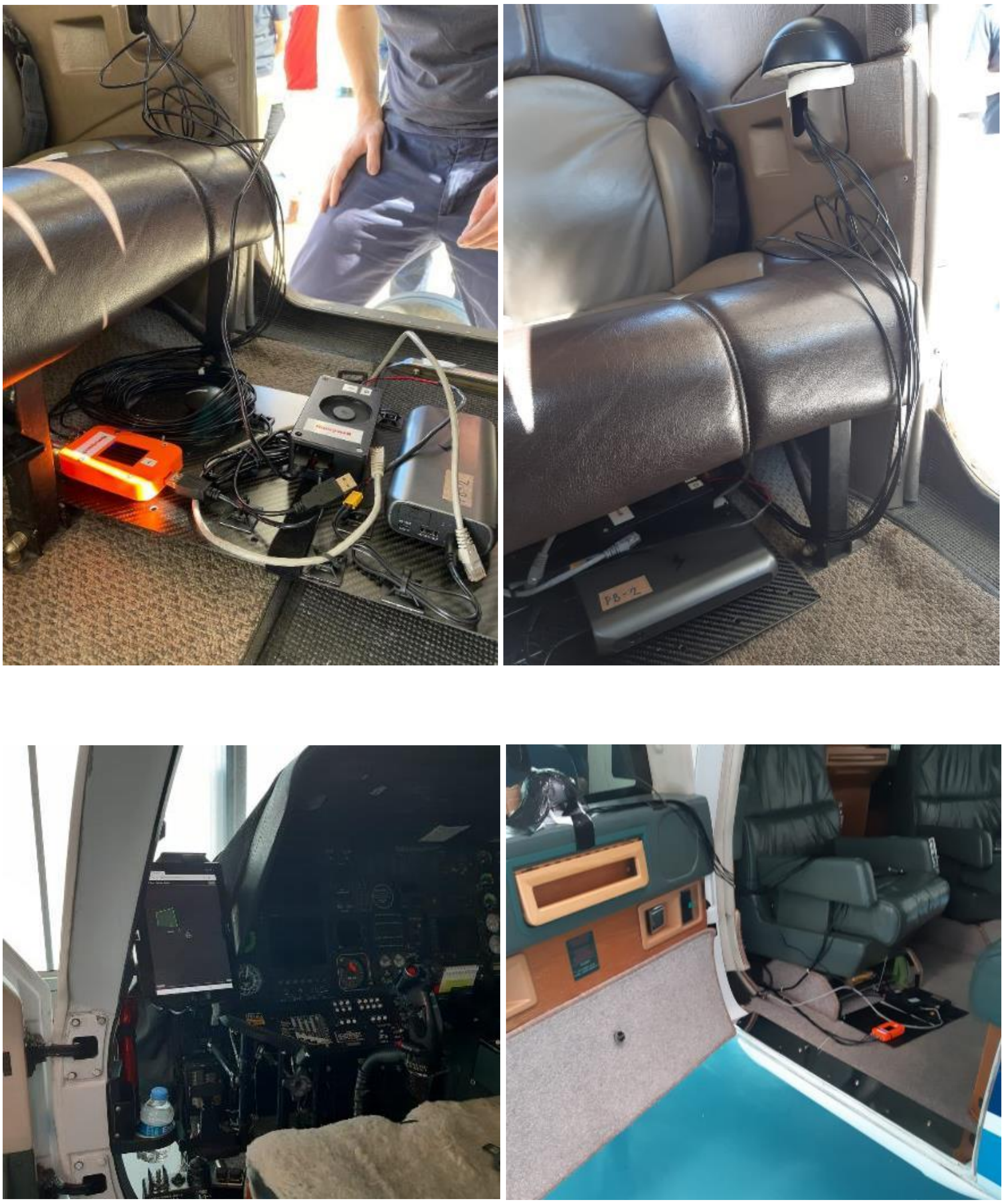


Figure 28. The device verification experiment on Cessna 172 aircraft and Sikorsky S76 B helicopter

Device validation experiment was performed Sarp Air with maintenance technicians and Captains with Honeywell researchers on the ground. The installation location and potential hazard were tested. Aircraft maintenance technicians provided their positive feedback for the validation setup. Tests were done on the ground.

Meanwhile, the performance of the communication channels with the ATC tower was evaluated. Aircraft maintenance technicians provided positive feedback for the verification setup. The report was submitted to the General Directorate of Civil Aviation as a procedure for the necessary flight permits.

5.1.5 Communication/Coordination-ESTU

ESTU played a coordinator role for all validation flights. Before the flights all parties were informed for the flights as Military base, ATCOs and pilots. During the flight days, Dr. Acikel (ESTU) and Dr. Turhan (UNSW Canberra) took position in the ATC tower as FACT actors for the central flight coordination role between air traffic controllers and flying operators for GA and drone. GA traffics were managed by the air traffic controllers and drone traffics were controlled by the Dr. Turhan and Dr. Acikel as communication enablers.

5.2 Execution

5.2.1 Flights

Depending on the scenario objectives, GA flights played their roles, and they communicated with ATCOs. ATCOs directed flights through the validation airspace and provided position information about the airplane and helicopter. FACT actors informed drone operators about the traffic situations in time. Regarding the drone battery capabilities and signal interface performance some scenarios were executed several times.

The post-flight illustrations of drones' routes and trajectories are shown below for all five scenarios.

5.2.1.1 Scenario 1 Execution

In the first scenario, a drone and a Cessna 172 were used. After executing engine start, push-back, taxi, and take-off, the Cessna 172 flew inside the predefined controlled flight area for the drone flying region, the drone planned a path to the defined geocage and proceeded its flight after receiving authorization from UTM. The airspace used in this scenario was uncontrolled airspace. Drone operator was informed by the FACT agents in the tower within the coordination of tower controllers about the Cessna 172 departure and proceeding through the testing area. All pilots were informed of the status of all aircraft in the flying area. There was no risky situation between the planes and the drone in the scenario. The Drone A flight log from scenario 1 is shown in Figure 29.

Figure 29. The Drone A flight log from scenario 1

5.2.1.2 **Scenario 2 Execution**

A drone and a Cessna 172 were flown in the second scenario. The Cessna 172 aircraft took off towards its predetermined flight areas after completing engine start-up, push-back, taxi, and take-off procedures. The drone flying in the specified territory crossed the flight area and entered the Cessna-172's flight area from a different altitude. When the drone entered the Cessna-172's flying area, the experimental CNC device delivered a warning message and forcing the drone to land, and drone landed. After being informed by Air Traffic Controls, the Cessna pilot proceeded his flight by performing an avoidance maneuverer. The Drone B flight log from scenario 2 is shown in Figure 30. Figure 31 depicts photos from the execution of scenarios 1 and 2.

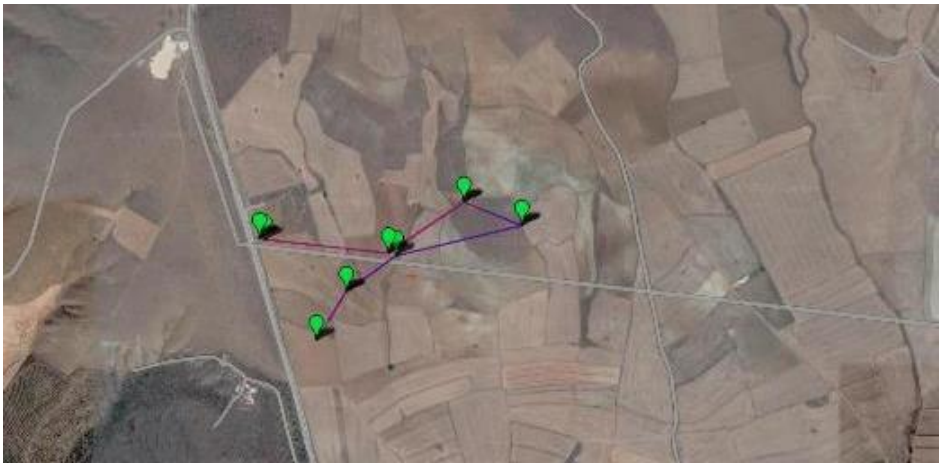


Figure 30. The Drone B flight log from scenario 2

Figure 31. The photos from Scenario 1 and 2 execution

5.2.1.3 Scenario 3 Execution

Two drones took flight role in the third scenario. When drone-A deviated from its trajectory in the defined flight area and entered drone-B's area, UTM warning message was sent. Drone operator-B, through ground control station, modified the drone’s flight plan and sent it to UTM. The operator of the drone-B completed its flight with UTM approval on a new flight route to avoid the other. Meanwhile, drone-A returned to its flying area. The Drone A and B’s flight log from scenario 3 are shown in Figure 30. Figure 32 depicts photos from the execution of scenario 3.

Figure 32. Drone A and B’s flight log from Scenario 3

Figure 33. The photos from scenario 3 execution

5.2.1.4 Scenario 4 Execution

In the fourth scenario realized in the controlled flight area, two drones and a helicopter flew. Both drones were flying in their designated flight areas as planned. When the helicopter entered the flight area of one of the drones, ATC warned the helicopter pilot with verbal information. The drone completed its flight towards to the geofence defined by UTM. The Drone A and B's flight log from scenario 4 are shown in Figure 34.

Figure 34. Drone A and B flight log from Scenario 4

5.2.1.5 **Scenario 5 Execution**

In the fifth scenario, a drone and a helicopter flew in the controlled flight area. The drone entered the helicopter's allocated areas. The helicopter pilot was informed by ATC. Due to the experimental CNC devise, the drone operator realized the situation and returned the drone to the flight area. The Drone B flight log from scenario 5 is shown in Figure 35. Figure 36 depicts photos from the execution of scenario 3.

Figure 35. Drone B flight log from Scenario 5

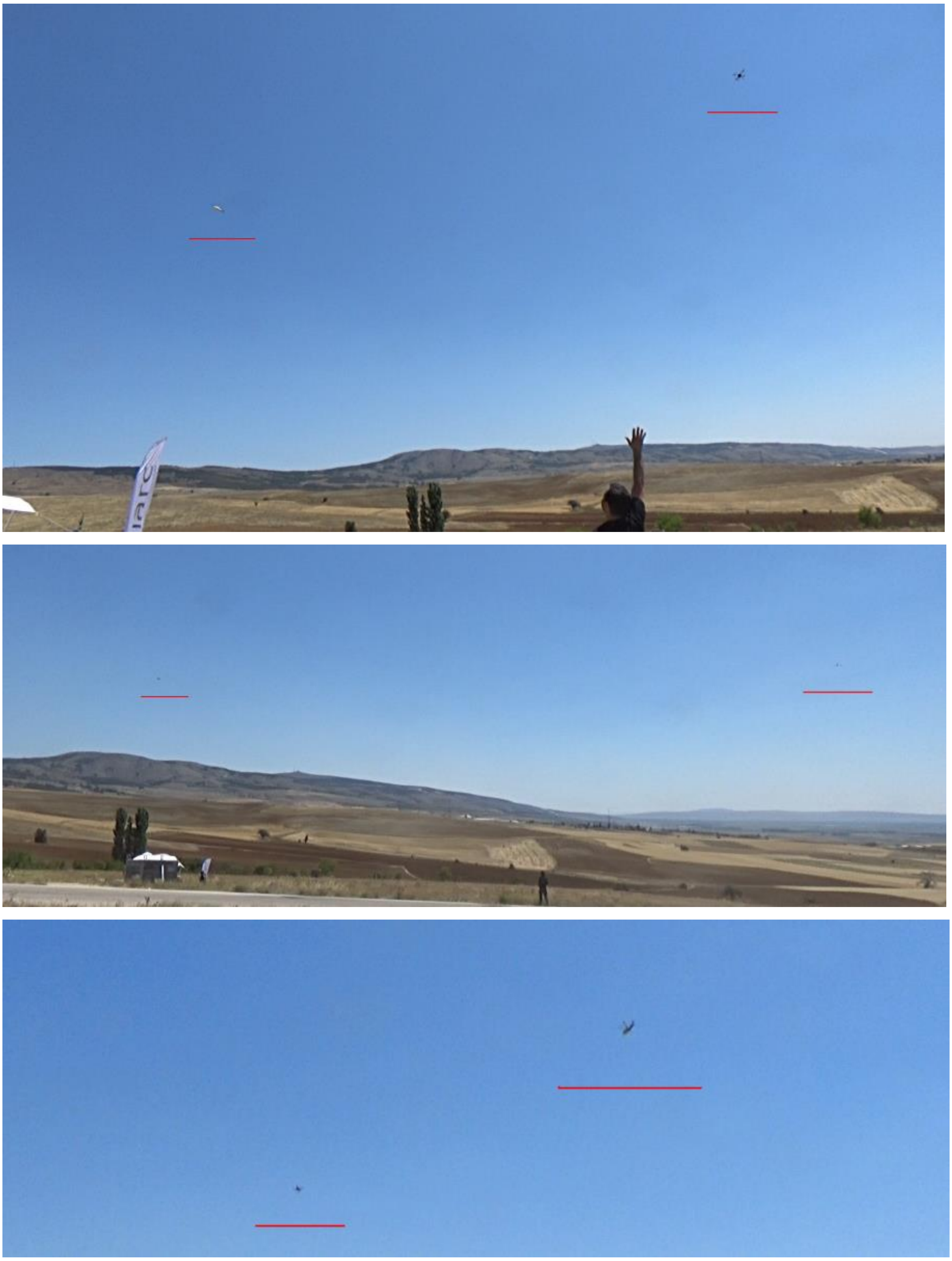


Figure 36. The photos from Scenario 4 and 5 execution

5.2.2 Situational awareness

During the FACT validation flight tests, situational displays were provided to the ATCOs to better understanding and situational awareness for their flights and other traffics.

On the drone operator side, the situational awareness was achieved through the patches added to the ITU ARC ground control station software. The operator tracked the positions and movements of the drones and GAs on its own screen.

In addition, an overall situation awareness display showing all involved traffic and status of communication among individual CNS devices was used by Honeywell to monitor progress of the scenarios.

5.2.2.1 Pilots

For Situational awareness, an experimental display unit which was connected to the CNS device. Unfortunately, due some technical issues which were not fully understood it did not show traffic information to the pilots what did not allow to evaluate this function. Well prepared scenarios and the vertical separations allowed aircrafts (fixed wing and rotary wing) to fly safely through the scenarios.

For each of the drones in the tests, a pilot followed the flight with an RC controller for safety purposes throughout the flight. There was no risky situation that required pilot intervention in the flights. The drone operator, on the other hand, controlled both drones simultaneously with separate ground control station software and followed other aircraft on the screen.

5.2.2.2 ATCOs

The display which was created by ESTU for the validation operational environment was introduced to the air traffic controllers. Their feedback was positive about the design and 3D visualisation of the interface. They provided feedback as display has the potential to improve ATCO situational awareness. Particularly they could not have the operational display in their tower working positions. The FACT interface provided them better understanding about the traffics in their responsibility airspace. They conveyed their positive recommendations about the visuals required for ATC, which should be added to the interface, to their project partners. The validation testing videos of the tested demo display can be seen in the links below:

1.mp4 - Google Drive

2.mp4 - Google Drive

ATCOs also provided their feedback as they would like to have direct communication with drone pilots and other pilots who can be included in the interface loop.

6 Validation Safety Assessment

6.1 Safety Assessment and Mitigation Plan for Operational Scenarios

During the validation studies FACT partners flowed the risk management methodology given in the D5.2. Furthermore, proactive risk management approach was performed by the partners. When required any change for the scenarios and operations partners evaluated potential hazards and made collaborative decisions.

6.2 Safety Assessment and Mitigation Plan by Honeywell

The applications enabled by experimental CNS device are used within the operational demo only as supporting applications enhancing situation awareness and therefore safety of the flight and traffic (separation) management are not directly relying on them.

Real implementation of procedural means established in the D5.2 as follows:

- Procedural means included in the operational scenario definition were based on strategic deconfliction process.
- When a non-conformance is included in the scenario, it is always complemented with additional safety buffer in other dimensions. For instance, when a horizontal deviation from planned trajectory is anticipated, the flights are always sufficiently segregated vertically to mitigate any potential safety risk.

  Post-flight status: Vertical separation was defined with sufficient safety margin (flight altitude of drones was 150 ft, flight altitude of GA aircraft for 650 ft)
- All flights are performed under Visual Meteorological Conditions and Visual Line of Sight (for drones) to enable visual check/monitoring of the situation by pilots/operators.

  Post-flight status: All flights were performed as flights per visual flight rules.
- In case of missing position reports, ground tracking service is performing coasting (extrapolation) of the vehicle position based on past positions if the interval from the last report do not exceed a pre-defined threshold (if the threshold is exceeded a warning is issued and traffic position is not provided).

  Post-flight status: Tracking service was deployed both on ground and on board the GA aircraft for smooth output to situational awareness application.
- There will be an operational demo observer who will monitor in real time on-going scenario and will alert the affected users or stop the scenario when needed.

  Post-flight status: Marketa Palenska was serving role of an operational demo observer. Emergency message (“stop scenario”) was predefined for potential use. Emergency group call for ground participants was established. There was no need to put these measures into practice.

- When needed it is always possible to alert and instruct pilots via voice links (VHF for GA pilots, or VoIP for remote pilots).

  Post-flight status: Voice links were ready to use in urgent case. There was no need to put these measures into practice.

6.3 Safety Assessment and Mitigation Plan by ITU

Wind strength and the rate of change in direction were a risk for flights. In order to mitigate this risk, wind speed was measured before each take-off. Take-offs were carried out under 15 m/s wind speed. The flight was not carried out in the afternoon, when the change of direction and the change of speed began to occur. Scenario 3 has been moved to the second test day.

It was a risk for autonomous drones to go out of the determined scenario area by mistake. In order to prevent drones from escaping outside the test area, the radius of the autopilot geocage was determined to cover the scenario area polygon and the risk was mitigated.

The energy consumed by the drones and the payload during pre-flight activities could have caused the battery not to provide sufficient flight performance. In order not to take off with a low battery, the battery cell voltages were measured for the last time before each take off. Also, prior to flight, the drones were powered from a DC power supply rather than a battery.

6.4 Safety Assessment and Mitigation Plan by AOPA

AOPA was involved in first operational validation and contributed to the definition of test scenarios. Within operational demo activities, AOPA reviewed and contributed some ideas to test cases refinement considering the given restrictions benefiting from its experience with the confusion of mixed traffic information generated by ADS-B, FLARM, others or not at all. Although observations of test flights from the ATCO's point of view had not been possible due to limited space in the tower, AOPA observed execution of scenarios from drones' operations centre, talked with pilots, and participated in the joint concluding discussion with all participants.

6.5 Safety Assessment and Mitigation Plan by SARPAIR

During actual flights and validation studies we as pilots followed the risk management methodology given in the D5.2. Proactive risk management approach with regards to all partners experiences were performed no risk faced during the test period. When required any change for the scenarios and operations partners evaluated potential hazards and made collaborative decisions.

D 5.2 section 5 were stating: “In addition, having a situational awareness application (interface) for all airspace users will minimize possible incidents and accidents” shall be considered for the real-world applications. As a pilot, I really need to see on a suitable application where the drone is and what is its intention at least in 5 NM around me while flying GA. And also, this system shall make necessary calculations and provide a warning for probable collision.

6.6 Safety Assessment and Mitigation Plan by ESTU

ESTU as national responsible partner for the FACT validation tests coordinated all partners for the required risk management and mitigation activities. For this perspective proactive risk management approach was followed. ESTU invited Dr. Turhan for the coordination of validation activities who was involved in the FACT studies and validation leadership. The risk management process can be divided into two phases as pre-validation activities and validation execution activities.

Before the execution of scenarios, ESTU managed:

- All required authority approvals for the flight trials by making detailed applications,
- All stakeholder communications and organization,
- Hazard identification and evaluation within the partners,
- Airspace definition,
- Aircraft device setup,
- Meetings with air traffic controllers and pilots,
- Collaboration with airport authority and campus personnel.

During the real time scenarios execution:

- Flight coordination activities from aerodrome tower,
- Real time hazard evaluation for the flights,
- Communication with local authorities such as airport management and military air base,
- Collaborative decision for flight safety.

7 Results of Validation

7.1 ATC View

FACT validation studies mainly precepted positive by the air traffic controllers who controlled the GA traffics with the external coordination of FACT project actors in the tower for drone pilot communications and control. Their main concern was drone operators' aviation competencies for the CNS device communication since they do not have formal education about as ATCOs and Pilots. They also emphasized that the ability of all stakeholders in the operation (helicopter and aircraft pilots and ATCOs) to communicate with each other in the current air traffic, but not being able to communicate with the drone operators in drone operations, creates a disadvantage and stress.

On the other hand, they were happy about the situational display benefits of the project. ATCOs are aware of new upcoming complexity about drone flights to be controlled in their airspace. For this reason, they see FACT project as values added.

7.2 Pilot's View

Pilots' View on Experimental CNS Device as following.

A meeting was held to obtain the evaluation and assessments of the pilots of the Cessna 172 SP fixed wing aircraft (Capt. Ozkan Yuksek) and Sikorsky S76 B helicopter (Capt. Mustafa Oguz Diken). Overall, both pilots understood the overall objective of the project as laying the foundations for low-cost, reliable CNS device that can be used to track drone traffic and increase situational awareness. Unfortunately, neither of the pilots were able to use the pilot's traffic situation awareness application during the flight tests due to technical difficulties. However, they both stated that such type of application will be of great use in terms of situational awareness although a proper HMI design will be crucial to do not overwhelm pilot with unnecessary details in busy areas.

During the meeting, one recommendation for improvement was suggested by Capt. Diken. Rather than being a static tracking device, the experimental CNS device can be further enhanced by adding capabilities similar to those of TCAS systems[2]. That way, the system can further increase the situational awareness, thereby increasing flight safety while reducing the workload on airmen.

[2] Such Detect And Avoid functions already exist and/or are under development (e.g., different variants of ACAS X system) but their evaluation was not in the scope of the FACT project.

7.3 Communication and CNS

7.3.1 Scenarios from CNS Point of View

All five scenarios were flown per Flight test cards in Appendix B of this document on Thursday 21st July. Scenario 3 was repeated on Friday with getting approval to use ADS-B Out. Generally, all five scenarios were completed.

During the flight of some scenarios, there were some minor technical problems that affected the measurement of communication parameters. For illustration, during run of Scenario 3 we handled the situation with insufficient strength of USB connections which whose gradual disengagement at vibrations was causing a loss of connection between drone and Flight Control Computer.

Next reason affecting performance was repeated HW restarts of experimental CNS units. The experimental CNS unit is designed in a way that if some SW component fails for fifth time in given time period, the whole unit is restarted. Such restart means communication outage from higher tenths of seconds up to one second. Any single component fail triggers a component reinitialization which affects communication slightly. Results for latency were processed in both ways – including these delays (because they represent real operation of the unit) and without these delays (because the reason of higher latency is not related to communication).

The component which causes these periodical fails was SW component responsible for direct monitoring of mobile network (signal quality parameters measurement). This component was receiving answer for given AT command which it did not expected (caused by some differences of Turkish network). Unknown response was not able to be parsed, so the component has failed and reinitialized again. The illustration of periodical increase in communication latency caused by periodical reinitialization of SW component is shown in Figure 37.

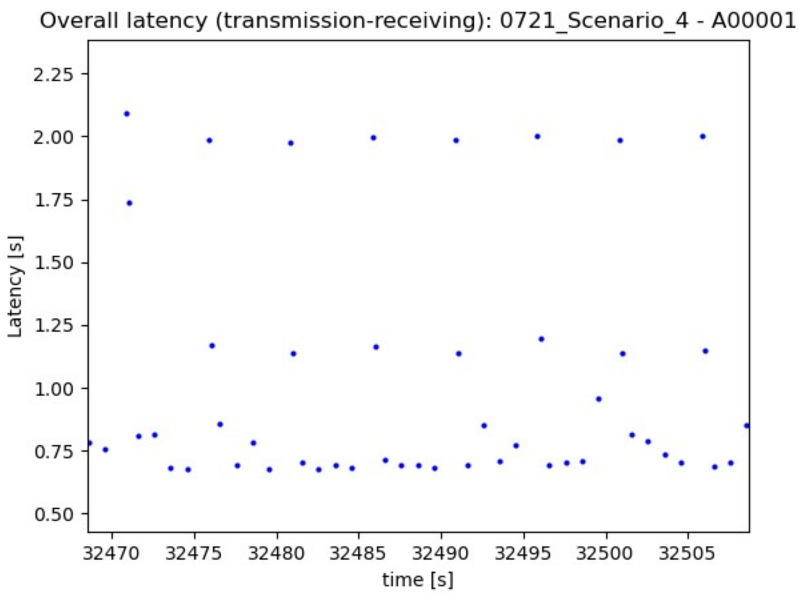


Figure 37. Illustration of periodical increase in communication latency caused by periodical reinitialization of SW component (the highest latency values conforms situation when reinitialization occurs on both onboard units)

7.3.2 Communication Results of Delivering Position Reports

Each Experimental CNS device logs all transmitted and received messages with current timestamp. On devices connected to internet via mobile network are synchronized via network time. This enables direct measurement of time between message transmission on vehicle A and message reception on vehicle B. This time difference is called *overall latency transmission – reception* and represent valuable evaluation parameter for onboard vehicles communication. Figure 38 depicts the flight demo architecture with marked overall latency transmission and reception.

Latency of processing on ground was also measured. Naturally, its values represent small part of the overall latency.

The most representative scenarios 1 and 4 was chosen for latency results presentation.

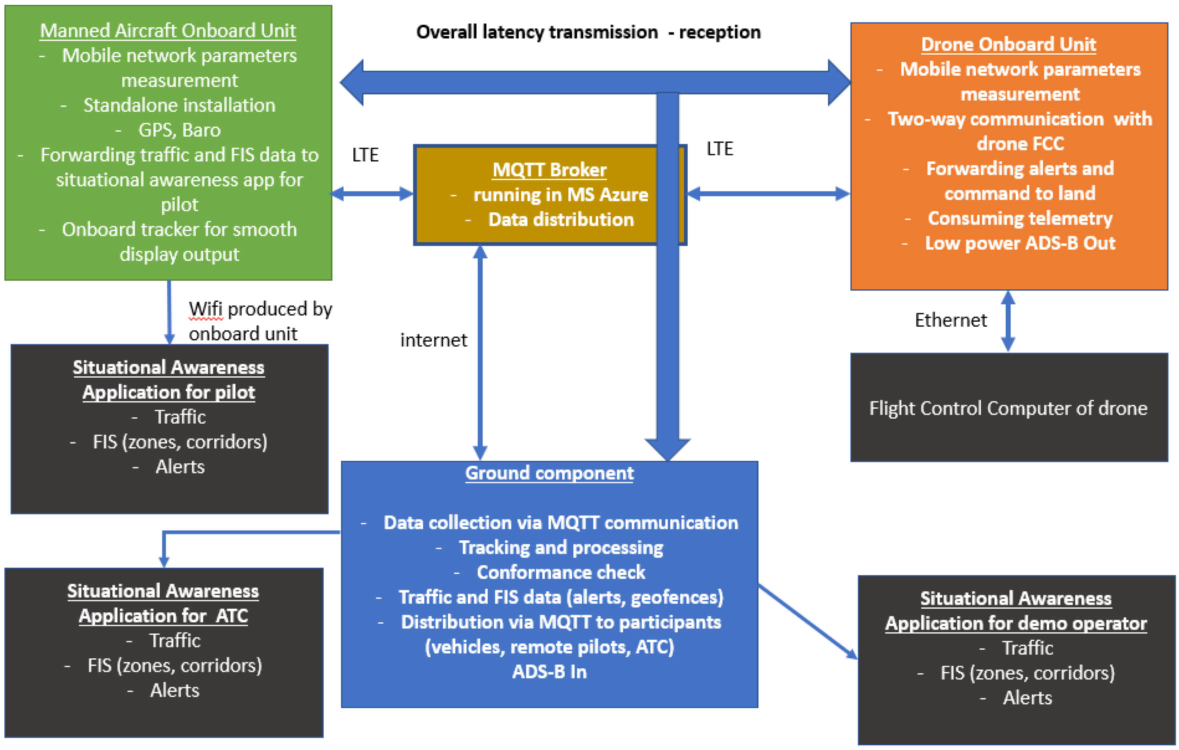
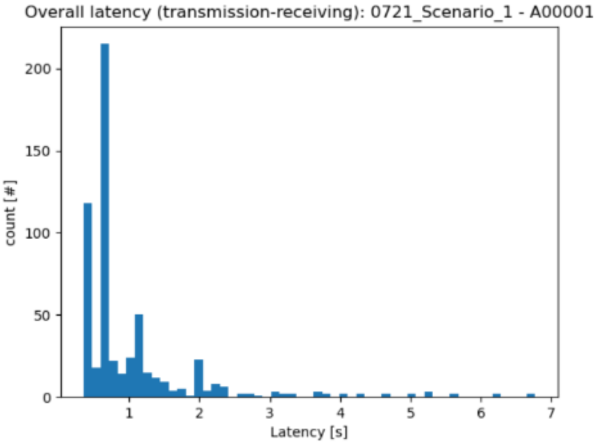


Figure 38. Flight demo architecture with marked *overall latency transmission – reception*

Co-funded by the European Union

7.3.2.1 Transmission – Reception Results for Scenario 1



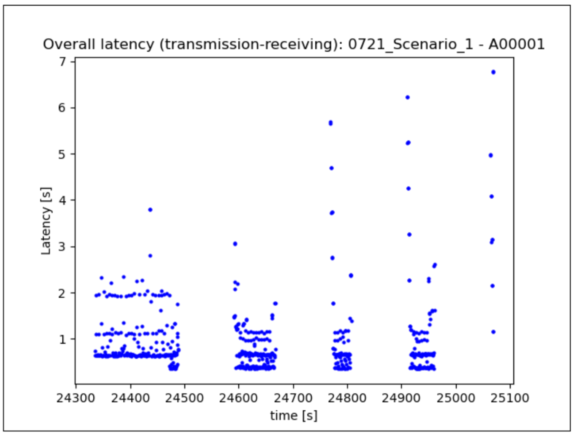
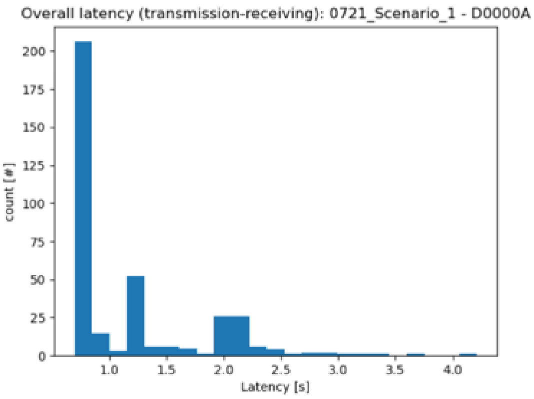


Figure 39. Overall latency transmission on aircraft – reception on drone A – Scenario 1

Left plot on Figure 39 shows histogram of measured latencies. It is evident that majority of values is under 1 second. Outages visible on right plot are caused by HW restart of the unit.



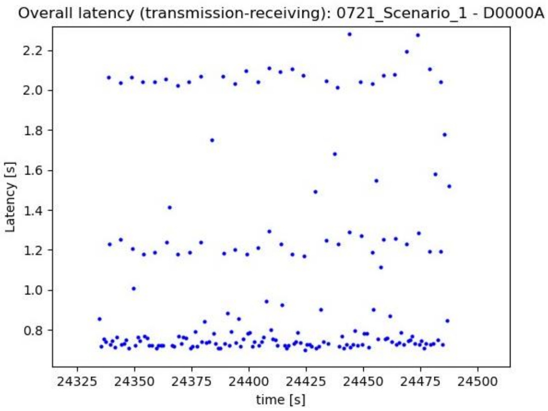


Figure 40. Overall latency transmission on drone A – reception on aircraft

Left plot on Figure 40 shows majority of latencies under one second. Periodic behaviour on right plot is caused by periodic component reinitialization as described in the Section 7.3.1.

In order to correctly evaluate latency, there is a need to ignore periodic latency spikes caused by component reinitialization. The median value can serve well for this purpose. The overall latency transmission – reception between drone and aircraft for Scenario 1 is shown in Table 4.

Table 4. Scenario 1, overall latency transmission – reception between drone and aircraft

	Drone A - Aircraft	**Aircraft – Drone A**
Overall latency transmission – reception [s]	1.16 (st. dev. 0.61, min 0.69, max 4.2)	1.03 (st. dev. 0.96, min 0.35. max 6.78)
Median value for latency transmission – reception [s]	**0.77**	**0.67**

Latency on ground [s]	0.06 (st. dev. 0.14, min 0.01, max 3.64)	0.05. (st. dev. 0.14. min 0.01, max 2.61)
Message loss from vehicle to ground (not only in outages)	4.38 %[3]	19 % / 5.11 %[4]

7.3.2.2 Ground Processing Latency – Scenario 1

The latency contribution caused by processing on ground server – messages from drone A for scenario 1 is shown in Figure 41.

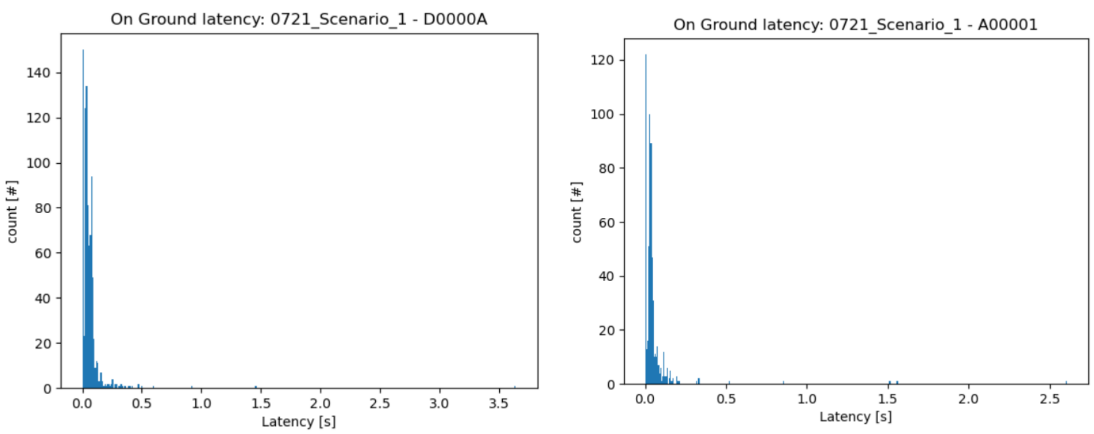
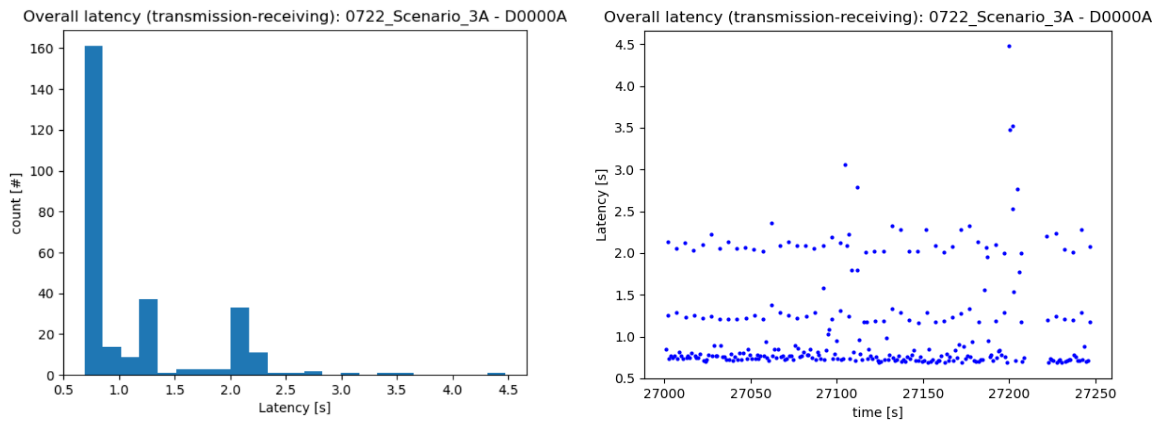


Figure 41. **Latency contribution caused by processing on ground server – messages from drone A (left plot) and messages from aircraft (right plot)**

7.3.2.3 Transmission – Reception Results – Scenario 3



[3] No significant outage in communication from Drone A to Aircraft.

[4] Including / excluding outages caused by restarting of the unit – see Figure 39

Figure 42. Overall latency transmission on aircraft – reception on drone A – Scenario 3

Left plot on Figure 42 shows majority of latencies under one second. Periodic behaviour on right plot is caused by periodic component reinitializations (doubled value when it occurs on both transmitting and receiving unit) as described in the Section 7.3.1. No HW restart occurs on drone A during Scenario 3.

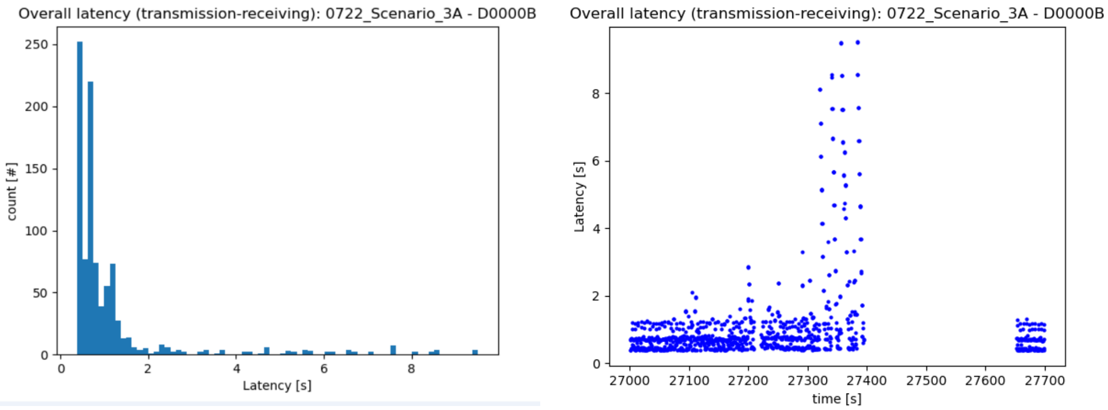


Figure 43: Overall latency transmission on aircraft – reception on drone B – Scenario 3

The overall latency transmission on aircraft – reception on drone for Scenario 3 is shown in Figure 43. Table 5 shows the overall latency transmission - reception between drone A and drone B for Scenario 4.

Table 5. Scenario 4, overall latency transmission – reception between drone A and drone B

	Drone B – Drone A	**Drone A – Drone B**
Overall latency transmission – reception [s]	1.14 (st.dev 0.61, min 0.68, max 4.47)	1.16 (st.dev 1.46, min 0.37. max 9.51)
Median value for latency transmission – reception [s]	**0.79**	**0.72**
Latency on ground [s]	0.055 (st.dev 0.049)	0.047 (st.dev 0.099)
Message loss (undelivered messages)	4.71 %	38.31 / 5.84 %[5]

[5] This huge message loss is affected by significant outage in the second half of scenario. Omission of this outage gives results of 5.84 % messages undetected on ground.

The location of drone B during outage when flying Scenario 3 is shown in Figure 44.

Figure 44. Location of drone B during outage when flying Scenario 3

7.3.2.4 Ground Processing Latency – Scenario 3

The latency contribution caused by processing on ground server – messages from drone A (left plot) and messages from drone B (right plot) is shown in Figure 44.

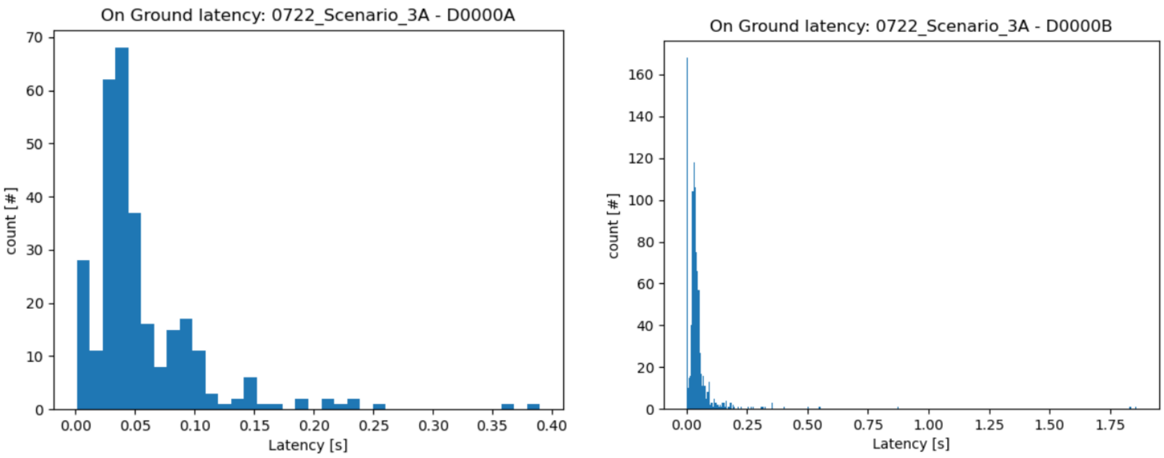


Figure 45. Latency contribution caused by processing on ground server – messages from drone A (left plot) and messages from drone B (right plot)

7.3.2.5 Conclusions

Scenario 1 and Scenario 3 results demonstrate representative latency values. Median latency values are around 0.7 second for end-to-end communication between two on-board vehicles including ground server processing. This result can be considered as conforming for applications like position reporting.

Continuous outages represent more serious issue than non-delivery of some individual messages. It is important to correctly distinguish outages caused by HW restart of unit (typically lasting 35 – 60 seconds) from outages caused by loss of LTE signal.

7.3.3 HW restarts can be identified from Experimental CNS unit logs. AT commands were called regularly for detection of poor LTE signal. Unfortunately, some unexpected responses often caused fall of this SW component. Results from network monitoring are available in Section 7.3.4.Communication Results of Delivering On-Demand Messages – Alerting

Alert messages were delivered by the same technological means as regular position reporting. Due to criticality of this communication type, each alert was produced repeatedly. Communication latency was not evaluated separately from position reports, but percentage of received messages on vehicle was assessed. The percentage of alerts received on affected onboard unit during scenarios are shown in Table 5.

No alert was produced in Scenario 4 (this is intentional behaviour – see Flight test cards in Appendix B).

Table 6. Percentage of alerts received on affected onboard unit during scenarios

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 5**
Percentage of alerts received on vehicle	100%	NA	80%	60%

7.3.3.1 Conclusions

Repeated transmission of on-demand messages was effective solution how to maximize probability of message delivery. All alert messages were delivered.

Increasing criticality of this communication will probably require some additional technical mean, e.g. confirmation of reception or similar.

7.3.4 Mobile Network Monitoring

Following values were continuously monitored during flight - Reference Signal Receive Power (RSRP), Reference Signal Receive Quality (RSRQ), Signal to Interference plus Noise Ratio (SINR), RSSI (Received Signal Strength Indication) and number of handovers between different base stations.

7.3.4.1 Results – Scenario 1

The parameters obtained via AT commands from unit installed on aircraft for Scenario 1 are shown in Figure 46.

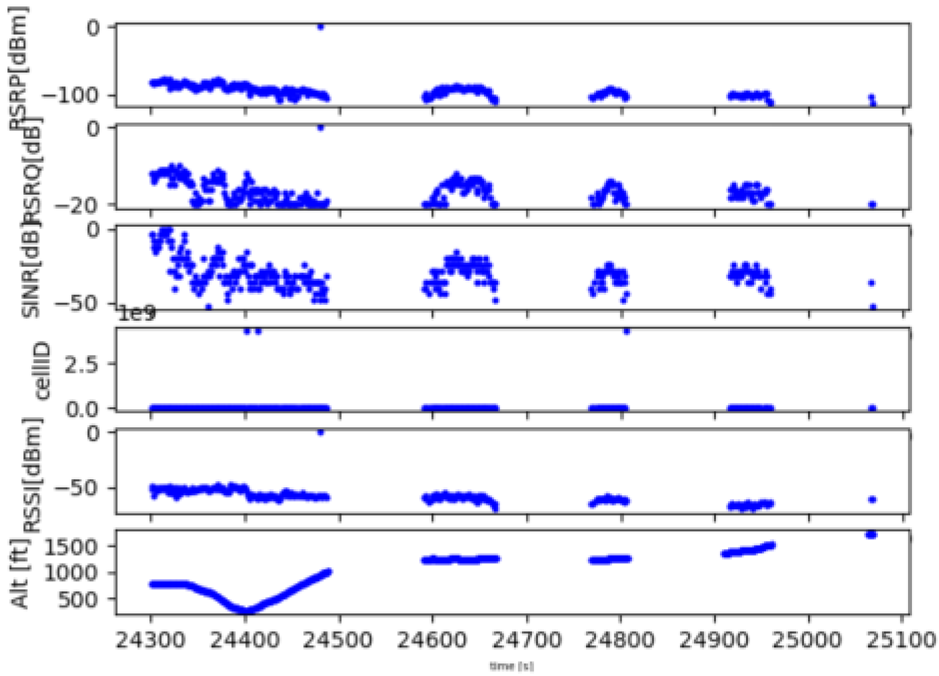


Figure 46. Parameters obtained via AT commands from unit installed on aircraft, Scenario 1

The results from network monitoring of aircraft unit for scenario 1 is shown in Table 7.

Table 7. Results from Network Monitoring, Aircraft Unit, Scenario 1

Parameter	**Value at Experimental CNS unit on Aircraft**	**Parameter**	**Value at Experimental CNS unit on Aircraft**
RSRP	**-91.4 dBm** average 8.8 st. dev. -112 min	**RSRQ**	**-16.4 dB** average 3.1 st. dev. -20 min
SINR	-29.0 dB average **10.1 st. dev.** -52 min	**RSSI**	**-56.3** average 5.5 st. dev. - 70 min
Handovers	4 handovers between 2 BTS		

7.3.4.2 Conclusions

Quantities related to connection quality parameters of mobile network are correlated with aircraft altitude. RSRP, RSRQ and SINR continuously decrease with increasing altitude. Parameter RSSI is not so strongly affected. This behaviour is expected because LTE public network is not optimized for aerial coverage.

7.3.4.3 Results – Scenario 4

The parameters obtained via AT commands from unit installed on aircraft for scenario 4 is shown in Figure 47.

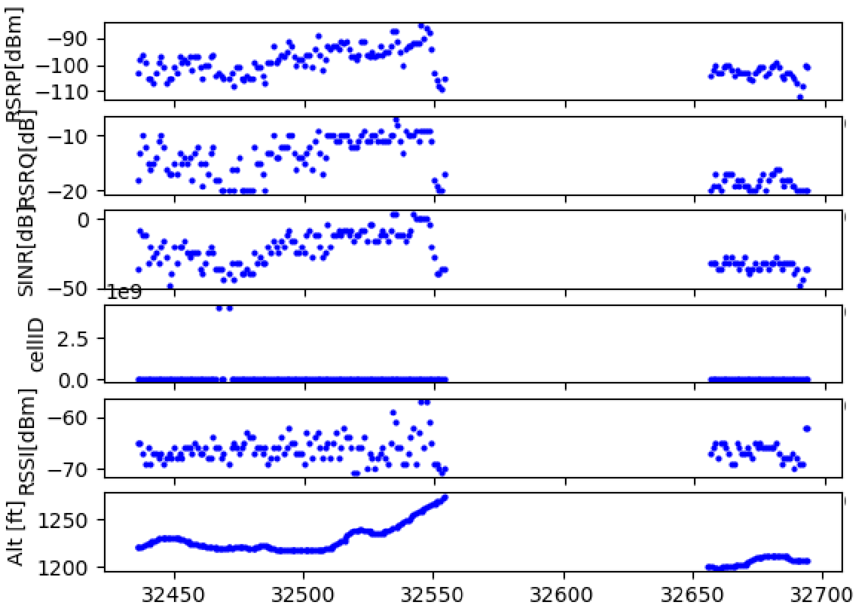


Figure 47. Parameters obtained via AT commands from unit installed on aircraft, Scenario 4

Plots above show parameters obtained via AT Commands on aircraft experimental CNS unit. Situation described here shows situation where quality parameters of mobile network connection gradually degrade until the point when the signal is lost. Values of RSRSP below -100 dBm mean that signal is very poor. The outage caused by LTE signal has last about 100 seconds. The results from network monitoring of aircraft unit for scenario 4 is shown in Table7.

Table 8. Results from Network Monitoring, Aircraft Unit, Scenario 4

Parameter	**Value at Experimental CNS unit on Aircraft**	**Parameter**	**Value at Experimental CNS unit on Aircraft**
RSRP	**-92.7 dBm average** 8.8 st. dev. -112 min.	**RSRQ**	**-16.5 dB average** 2.9 st. dev. -20 min.

SINR	**-29.5 dB average** 9.6 st. dev. -52 min.	**RSSI**	**-56.3** average 5.5 st. dev. - 70 min
Handovers	4 handovers between 2 BTS		

7.3.4.4 Conclusions

Similarly, at results for Scenario 1, we can also observe expected behaviour in form of decreasing quality parameters together with increasing altitude. Unlike the Scenario 1 where loss of communication was caused by unit restarts, Scenario 4 shows very probably communication loss caused by poor mobile network signal. Plot on Figure 47 shows massive decrease of quality parameters in time 32 550 before the communication outage.

7.3.5 Position Reporting Via ADS-B versus Mobile Network

Scenario 3 was flown twice on Friday 22nd July with Drone A equipped with ADS-B Out portable unit. Received ADS-B messages were logged on ground. The uAvionix SkyEcho produces three types of ADS-B messages – position report, velocity report and status message. Position and velocity report are nominally produced twice a second, whether the status message is produced with period of 2.5 seconds.

Position report produced by experimental CNS unit is sent approximately once per second. During two Friday scenarios a comparison of messages lost were performed with following results (Table 9):

Table 9. Message loss at position reporting, Scenario 3

Technology	Messages Produced On-board	Messages received on ground	Message loss
ADS-B (position – velocity – status message)	180 – 181 - 36	**133 – 137 - 26**	25.4 %
Position Reports via LTE	102 / 88[6]	**63 / 63**	38.3 % / 28.4 %

[6] Results including / excluding message loss caused by LTE outage.

Percentual message loss was higher using LTE network than ADS-B. It is important to mention that such high message loss during this Scenario was affected by outage lasting 14 seconds when messages cannot be received . This outage was not caused by restart of the unit (too short period), so the cause was very probable lack of LTE signal.

Overall latency (transmission – receiving): 0723_Scenario_3B_D000A

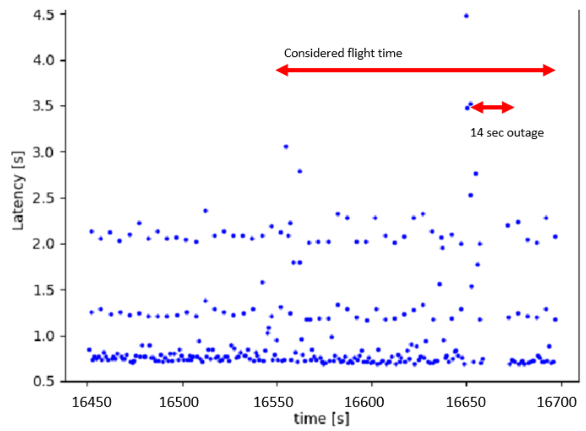


Figure 48: Documented outage during transmission of position reports over LTE from Drone A

Figure 48 shows outage lasting 14 seconds during Scenario 3 at Drone A. This outage conforms to loss of 14 messages. When excluding these messages from evaluation, message loss rate is 28.4 %.

7.3.5.1 Conclusion

There were observed significant message loss at both technologies. Approximately 10 % of messages transmitted over LTE were lost due to outage documented on the plot. The rest of lost messages were very probably caused by some issues in RF signal propagation (attenuation by relatively high signal to noise ratio observed at Drone A).

ADS-B message loss cause cannot be precisely identified because ADS-B Out is COTS product which does not provide too much information for deep analysis. Generally, it can be said that such messages loss is not atypical (see [8] stating a mean message loss about forty percent even at short distances). Very probably major cause is so-called doughnut effect (higher message loss in close horizontal distances to transmitter).

General conclusion is that there is no major issue at tenths percent of messages lost when this situation occurs regularly and not in longer outages. Ground surveillance services use trackers which are able to manage situation with high position message loss when at least some messages arrive regularly.

7.4 Drone's Operator View

A single person played the role of both drone operators simultaneously in the tests. The operator stated that overcoming the risks of flying in manned air traffic with UTM messages that provide situational awareness gives a feeling of safety. He stated that it is important to monitor conflicts and manage separations by UTM. Although there are outages in the 4G connection, he stated that the incoming data is sufficient to detect the surrounding traffic.

7.5 Conclusions

FACT second real time validation studies were performed in the planned time duration within the harmony of the partners. Due to circumstances out of our control it had only been possible to run the flight tests with a cellular 4G LTE public network instead of a private 5G network (see Section 3.4 for more details).

In the table below, the outcomes of the second validation studies (operational demo) are summarised and compared with the corresponding validation plan described in D5.1.

Table 10: Coverage of Validation plan objectives for operational demo.

Validation Objective	Results/Conclusions	Comments
Performance of datalinks	As discussed in detail in Section 7.3, public network seems to have sufficient performance to support traffic surveillance application in very low altitude (~100m). Nevertheless, its use for alerting or safety critical applications is not recommended unless it is complemented with some additional technologies/means.	Results from the operational demo are only one component of the performance evaluations performed in the project. See D5.4 or D1.3 for overall conclusions.
Analyze potential interferences	Impact of interferences was clearly observed for GA/rotorcraft and also (weaker) for drones. See section 7.3 for more details.	Results from the operational demo are only one component of the interference evaluations performed in the project. See D5.4 to see the whole picture.
Load/complexity of the 5G E2E network.	Not accomplished. 5G Private network could not be established due to equipment unavailability. 4G and LTE technologies available at the test site (ESTU Campus) were used instead	Measurement of the impact of load in 5G network was measured in Brno with Technical University – the results are included in D5.4
Radio altimeter performance	Not addressed	These measurements were considered as potentially helpful in the context of 5G positioning evaluations which did not make sense in public LTE network.

Qualitative assessment of benefits for remote pilots, GA pilots, and ATCO	All interested parties provide positive feedback	
Measurement of the network performance in the ESTU campus	As the experimental flights were executed outside of campus, only data from that area were collected.	There were multiple additional (originally unplanned) data collections for public network (Poland, Czechia, Spain) so the goal of this objective was exceeded through complementary activities.
Use cases and scenarios – acceptability, feasibility	Addressed mainly during first validation (simulator sessions). During operational demo, no concerns with feasibility/acceptability of scenarios were raised.	
Geofencing performance and trajectory performance	Geofencing and trajectory performance in general met the expectation/scenarios needs.	There was temporarily impact of strong wind conditions during some of the scenarios, but without significant impact on demo objectives.
Risk/Emergency Management	During simulations, hazard identification was performed. On the real environment validations, a proactive risk management/mitigation approach was followed. All operational parties collaborated together for the best and safe options for the scenario executions including airspace stakeholders.	Despite all the foreseen and unforeseen risks, the risks were managed and the validation process of the project was completed successfully.
Situational awareness of ATCos	ATCos were informed in real-time and coordination was performed by the operational partners with precise communication. ATCOs reported that the FACT approach and drone and GA flight monitoring tools are useful for their SA.	ATCos have also had suggestions and criticisms regarding the interface. It was especially emphasized that the device will provide much more benefits, should their recommendations be taken into consideration

		during future development efforts.
Situational awareness of drone pilots	Positive feedback on value of this function/application received during operational flights.	Only an experimental (engineering) HMI design was used during operational demo, so detailed HMI aspects were not evaluated.
Situational awareness of aircraft pilots	GA pilots were informed about drone activities. Pilots reported that more accurate and on-time position information and rapid communication would be beneficial. They emphasize that their safety and operations have priority when compared the drones. Also, they discussed drone operator competencies and aeronautical knowledge. Unfortunately, due to technical issues it was not possible to collect feedback on cockpit situation awareness application during real flights.	

In summary, within our test scenarios traffic data and VoIP could be satisfyingly transmitted between ground stations and max 3 aircraft or drones. However, to plan for additional services such as:

- CPDLC, VoIP (broadcast and P2P),
- graphic weather reports (better than ATIS),
- flexible use of airspaces (FUA) and dynamic geofencing,
- broadcast of traffic information directly between all users without ground stations,
- download of operational data from aircraft or drones, e.g. remaining fuel or flight time

used by many more participants much higher data volumes have to be expected.

Another aspect is a seamless Europe-wide implementation of such services for all types of GA airspace users, operating sometimes far away from airfields. Assuming that 5G services are not available outside of densely populated areas soon and there will be neither continuous services on the ground 24/7, our results with 4G networks could provide a basis for planning an early implementation with a mixture of 4G/5G networks.

As stated in the introduction, the overall project's outcomes considering both the results of the operational demo presented in this report and the results from first validation phase and other complementary activities will be summarized in the Validation Assessment Report (D5.4) to be delivered shortly after this document.

8 References

[1] FACT Deliverable D2.3: "Final Concept of Operations", version 00.01.01, 2.9.2022

[2] FACT Deliverable D2.4: "Final iCNS Functional Architecture", version 00.01.00, 12.7.2022

[3] FACT Deliverable D3.3: "Final System Requirements", version 00.01.01, 2.9.2022

[4] FACT Deliverable D3.4: "Final Technological Demonstrators", version 00.01.01, 2.9.2022

[5] FACT Deliverable D5.1: "Validation Plan", version 00.01.01, 26.11.2021

[6] FACT Deliverable D5.2: "First Validation Report", version 00.01.01, 6.4.2022

[7] FACT Deliverable D5.4: "Validation Assessment Report", to be delivered in September 2022.

[8] M. Strohmeier, M. Schäfer, V. Lenders, I. Martinovic : Realities and challenges of nextgen air traffic management: The case of ADS-B, IEEE Communications Magazine, May 2014, available at: https://www.researchgate.net/publication/265783916_Realities_and_challenges_of_nextgen_air_traffic_management_The_case_of_ADS-B

Appendix A All Approval Documents

A.1 5G permission approval

Eskişehir Teknik Üni. Evrak Tarih ve Sayısı: 26.05.2022-72748

BİLGİ TEKNOLOJİLERİ VE İLETİŞİM KURUMU

K-Q TSE-ISO-EN 9000

T.C.
BİLGİ TEKNOLOJİLERİ VE İLETİŞİM KURUMU
Yetkilendirme Dairesi Başkanlığı

Sayı : E-98966759-157-32793

Konu : 5G Deneme İzni Talebi

DAĞITIM YERLERİNE

İlgi : a) Elektronik Haberleşme Sektöründe Deneme İzni Verilmesine İlişkin Usul ve Esaslar.
b) Eskişehir Teknik Üniversitesi Rektörlüğünün 07.04.2022 tarihli ve 84994412-604.99.03.01-E.66901 sayılı yazısı.
c) Eskişehir Teknik Üniversitesi Rektörlüğünün 27.04.2022 tarihli ve 84994412-604.99.03.01-E.69423 sayılı yazısı.

Eskişehir Teknik Üniversitesi tarafından ilgi (b) ve (c)'de kayıtlı yazılar ile özetle, Üniversitelerinin bir SESAR H2020 Projesi olan "FACT - Future All Aviation CNS (Communication, Navigation and Surveillance) Technology" Projesinin önemli partnerlerinden biri olduğu, "FACT" Projesinde, geleceğin hava sahası operasyonları ile 5G gibi geleceği şekillendirecek teknolojileri güvenlik, emniyet, verimlilik ve esneklik ölçütlerini dikkate alarak bir araya getirmenin yollarının araştırıldığı, CNS teknolojileri ile hem genel havacılık hem de insansız hava araçları için operasyon senaryolarının hazırlanmış olduğu, projenin uygulama aşamasının Üniversitelerinde gerçekleştirileceği ifade edilmiş olup, projenin uygulama aşamasında 5G teknolojisi ile proje kapsamındaki hava araçlarının gerçek zamanlı konum, hız ve yön gibi bilgilerinin hava trafik yönetimi ve veri akışı açısından değerlendirilmesi amacıyla geçici olarak kurulacak 5G altyapısı için frekans tahsisi suretiyle deneme izni verilmesi talep edilmektedir.

Eskişehir Teknik Üniversitesi'nin söz konusu başvurusu kapsamında Kurumumuzca yapılan değerlendirme sonucunda, 3.4-3.5 GHz frekans bant aralığından toplam 100 MHz bant genişliğinin, 15.11.2022 tarihine kadar Eskişehir Teknik Üniversitesinde (39°48'56"K, 30°31'49"D), 1 adet baz istasyonu, 4 adet TRx ile deneme amaçlı kullanımı uygun görülmüş olup, Eskişehir Teknik Üniversitesi'nin ücretten muaf olması sebebiyle ücret fişi oluşturulmamıştır.

Diğer taraftan, anılan frekans bandında ve komşu bantlarda mevcut kullanımların olması ve diğer kullanıcılara da izin verilebilecek olması nedenleriyle, deneme izni sürecinde diğer kullanımlara elektromanyetik girişim oluşturulmaması amacıyla gerekli önlemlerin Eskişehir Teknik Üniversitesi tarafından alınması, herhangi bir girişime maruz kalınması halinde kullanımın derhal sonlandırılması ve bu durumun Kurumumuza ivedilikle bildirilmesi gerekmektedir. Bu kapsamda örneğin, 4.2-4.4 GHz frekans bandında çalışan radyo yükseklik ölçerlere (radio altimeters) herhangi bir olumsuz etki oluşturulmaması için tüm baz istasyonlarının yükselme açısının aşağı yönlü (downward tilt) olması ve baz istasyonlarının gücüne bağlı olarak iniş-kalkış yapılan pist noktalarına belirli mesafede (azami olarak 78 dBm eirp gücünde çalışan baz istasyonu için en az 1000 m., gücün 10 dB düşürülmesi halinde ise en az 300 m. uzaklıkta) kurulması ile sınırlı olmamak ve saha uygulamasında gerektiğinde söz konusu kısıtlamaların artırılması dahil

Bu belge, güvenli elektronik imza ile imzalanmıştır.

Doğrulama Kodu: DF65C81E-9FE8-4C51-AC8F-0CFD7F58AD3D Doğrulama Adresi: https://www.turkiye.gov.tr/btk-ebys

Bilgi Teknolojileri Ve İletişim Kurumu
Eskişehir Yolu 10.Km No:276 Çankaya/Ankara
Tel: 0 312 294 72 00 Faks: 0 312 294 71 45
KEP Adresi : btk@btk.hs01.kep.tr

Bilgi için:Özkan ÖNCÜ
Bilişim Uzmanı

1 / 2

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olmak üzere gerekli tedbirlerin alınmaması nedeniyle ortaya çıkabilecek olumsuzlukların her türlü sorumluluğu başvuru sahibine aittir.

Eskişehir Teknik Üniversitesi tarafından, söz konusu deneme çalışmaları kapsamında ilgi (a) Usul ve Esasların 9'uncu maddesinde belirtilen yükümlülüklere uyulması, özellikle deneme çalışmalarına başlamadan önce baz istasyonu sertifikasyonu için Kurumumuzun ilgili Bölge Müdürlüğüne başvuruda bulunulması gerekmektedir.

Bilgilerinizi ve gereğini rica ederim.

Ömer Abdullah KARAGÖZOĞLU
Kurul Başkanı

Dağıtım:

Gereği:
ESKİŞEHİR TEKNİK ÜNİVERSİTESİ
REKTÖRLÜĞÜNE

Bilgi:
SPEKTRUM YÖNETİMİ DAİRESİ
BAŞKANLIĞINA
ANKARA BÖLGE MÜDÜRLÜĞÜNE

Bilgi Teknolojileri Ve İletişim Kurumu
Eskişehir Yolu 10.Km No:276 Çankaya/Ankara
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Bilgi için:Özkan ÖNCÜ
Bilişim Uzmanı

A.2 Flight permit/approval for Cessna 172 from the General Directorate of Civil Aviation for the FACT project

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*************** MANUALLY PRINTED   2022-07-20 17:24:33 ***************
<SOH>SAZ0028 20142357
KK LTZZSKXX LTAAYNYX LTACYWYX LTBAZPZX LTBJZRZX LTACYWYT LTAAYAYT

201423        LTAAYAYZ
<STX>
HSD410
PART 001
ILGI: ESTU HUBF OEO TR.039 UN 05/07/2022 TARIHLI YAZISI ILE
ASAGIDAKI PROGRAMA GORE UCUS MUSAADESI
TALEP EDILMEKTEDIR.

UCUS PLANI ILE UCUSUN ICRA EDILMESI

HAVA ARACI
TIPI-TESCILI:C.172-TC-SHN,C.172-TC-SHO,C.172-TC-SHR,C.172-TC-SHS,C.17
2-TC-SHT

UCUS AMACI: VERI AKTARIMI
UCUS TIPI: VFR
UCUS TARIH VE SAATLERI:21-29.07.2022  0630-0855 UTC VE 1105-1320 UTC
UCUS BOLGESI:ESKISEHIR
UCUS IRTIFASI: 3250 FEET MSL

UCUS YAPILACAK BOLGENIN KOORDINATLARI:
394835N0303110E MERKEZ OLMAK UZERE 1.5 NM YARICAPLI SAHA

INIS/KALKIS NOKTALARI:LTBY

BAHSE KONU UCUSLARDA:
-TURKIYE AIP'SI VFR UCUS KURALLARINA VE AIP HUKUMLERINE UYULMASI,
-UCUS PLANI DOLDURULMADAN 1 SAAT ONCE KULE ILE (05323511497) TEMAS
KURULUP ON MUSAADE ALINMASI,
-KULE TARAFINDAN VERILEN ZAMAN DILIMINE IRTIFAYA VE ATC
TALIMATLARINA UYULMASI,
-UCUSTAN 1 GUN ONCE ILGILI ATC UNITESI ILE KOORDINE KURULMASI VE
UYGUN GORULEN SAATLERDE UCUS PLANLANAMSI,PILOT SORUMLULUGUNDA OLMAK
UZERE YAKLASMA/ALCALMA VE TIRMANMA HATLARININ IHLAL EDILMEMESI,
-CALISMA SAHALARINDA CALISMA YAPILMASI DURUMUNDA CALISMA BOLGESININ
FREKANSINI BAGLAYARAK DIGER TRAFIKLERE BILGI VERILMESI,
-VFR UCUS SARTLARINA RIAYET, DIGER NOTAMLARA ILISKIN TAKIP
SORUMLULUGU,TRANSPONDER ARIZASINDA VEYA G/F OLMA DURUMUNDA
FAALIYETIN ICRA EDILEMEYECEGI VE EMG FRQ SUREKLI DINLEMEDE KALINMASI
KONULAR ILE GEREKTIGINDE UCUSLARIN DURDURULMASIDA DAHIL OLMAK UZERE,
ATC TALIMATLARINA TITIZLIKLE UYULMASI HUSUSLARA RIAYET EDILMESI
-BOLGEDEKI ASKERI BIRLIKLERLE GEREKLI KOORDINENIN YAPILMASI VE
ILGILI TALIMATLARA RIAYET EDILMESI KAYDIYLA FAALIYETIN ICRA EDILMESI,
-OLUR ALINMASI GEREKEN MEYDANLARDAN OLUR ALINMADAN UCUS PLANLANMAMASI
-TUM UCUSLARIN ISLETME VE PILOT SORUMLULUGUNDA GERCEKLESMESI

<VT><ETX>
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Appendix B Flight Test Cards and Scenarios

B.1 Scenario 1

Before flight:

Time	*Action*	*Responsibility*	*Message*
	Drone airspace allocated	ATC	fact-test/atc/airspace
	GA area allocated	ATC	fact-test/atc/airspace
	Free flight request submittal	Drone operator	fact-test/gcs/free_flight_request
	Free flight request approval	ATC	fact-test/utm/approval

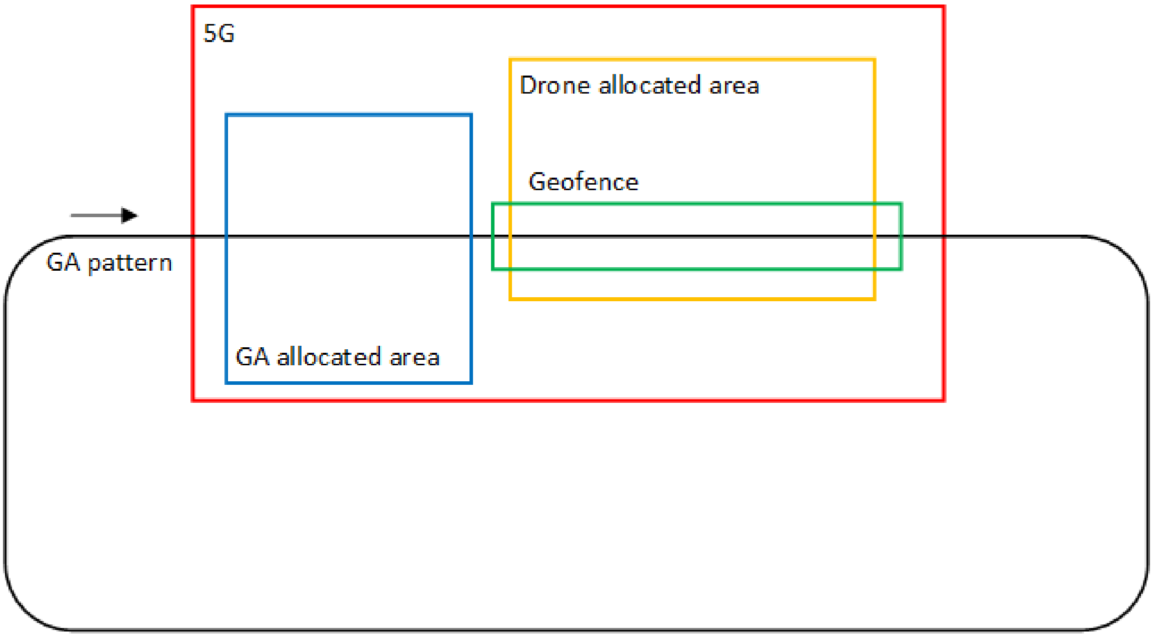
Flight

Time	*Action*	*Responsibility*	*Message*
T0-720 seconds	Engine start-up	ESTU	
T0-420	Request taxi from ATC	ESTU	
T0-390	Starting taxi from ATC	ESTU	
T0-90	Holding Point	ESTU	
T0-30	Permission for take-off from ATC	ESTU	
T0	Line-up and take-off clearance Cessna starts to perform its flight pattern at 2600 feet SL (Sea Level) (0 Feet AGL (Above Ground Level)) altitude defined by dimensions of (4345 x 11781) feet and corner coordinates:	ESTU	

	(39°48'32.88N, 30°32'29.04"E) Corner-1 for Cessna, (39°48'36.63"N, 30°29'53.76"E) Corner-2 for Cessna, (39°49'20.21"N, 30°30'18.06"E) Corner-3 for Cessna, (39°49'12.35"N, 30°32'45.75"E) Corner-4 for Cessna.		
T0+120	Cessna passes through corner-coordinate 2 (39°48'36.63"N, 30°29'53.76"E) and begins to crosswind flight pattern at 3250 feet SL (650 feet AGL) altitude.	ESTU	
T0+180	Cessna passes through corner-coordinate 3 (39°49'20.21"N, 30°30'18.06"E) begins to downwind flight pattern at 3250 feet SL (650 feet AGL) altitude.	ESTU	
T0 + 180	Drone A starts to perform its flight pattern at 2600 (0 Feet AGL) feet and corner coordinates for DroneA: (39°48'57.14"N, 30°32'20.74"E) Corner-1 for Drone, (39°49'15.36"N, 30°31'48.83"E) Corner-2 for DroneA, (39°49'31.17"N, 30°32'2.32"E) Corner-3 for DroneA (39°49'19.52"N, 30°32'29.05"E) Corner-4 for DroneA.	ITU	-
T0 + 200	The drone A reaches 2750 feet SL (150 feet AGL) for the flight pattern and starts to perform its trajectory defined by sequence of points	ITU	

	1. 39°49'14.17"N, 30°31'55.20"E Starting point 2. 39°49'18.04"N, 30°31'53.88"E 3. 39°49'21.05"N, 30°31'57.62"E 4. 39°49'23.09"N, 30°32'3.26"E 5. 39°49'18.33"N, 30°32'5.99"E 6. 39°49'16.65"N, 30°32'9.01"E 7. 39°49'23.74"N, 30°32'10.25"E 8. 39°49'13.79"N, 30°31'55.76"E		
T0 + 235	Cessna enters drone area (only in horizontal dimensions, there is safety margin in vertical separation) at given coordinates that is 39°49'15.36"N, 30°31'48.83"E) Drone Corner-2 Cessna passes through the area reserved for the drone in 20 seconds.	ESTU	
T0 + 236	Alert message is provided by UTM. Exp. CNS device will forward this message to drone FCC.	**Automated action (UTM)**	fact-test/UAV/A00001/alert
T0 + 236	Geocage is deployed with dimensions (900 x1000) feet and corner coordinates that are (39°49'16.13"N, 30°32'6.88"E) Geo2Crn1, (39°49'16.45"N, 30°31'59.78"E) Geo2Crn2, (39°49'26.85"N, 30°32'0.02"E) Geo2Crn3, 39°49'26.76"N, 30°32'6.89"E) Geo2Crn4 The distance between the Cessna path and the geocage border is 300 feet.	**Automated action (UTM) / HON**	fact-test/utm/geofence/1
T0 + 240	Drone operator via GCS changes flight plan to avoid geocage and provides it to USSP	ITU	fact-test/gcs/ flightplan/1

T0 + 241	UTM checks new flight plan and approves it.	**Automated action (UTM)**	fact-test/utm/flightplan/1/reply
T0 + 242	Drone operator conducts flight per approved flight plan	ITU	-
	Ground operator (Marketa) provides WhatsApp call about successful run. Haluk informs ATC and ATC provides info to pilot that they can land.	HON	



Note: Cessna can enter drone area from east due to current wind conditions. All participants will be informed about it before flight.

GA allocated area:

39.8065500N, 30.5467867E

39.8138356N, 30.5472586E

39.8151211N, 30.5388044E

39.8203953N, 30.5305647E

39.8164397N, 30.5253289E

39.8174286N, 30.5002664E

39.8078686N, 30.4988931E

Drone allocated area:

39,8158722, 30,5390944

39,8209333, 30,5302306

39,825325, 30,5339778

39,8220889, 30,5414028

Drone geocage:

39,8207725, 30,5358357

39,8209007, 30,5370398

39,8207725, 30,5358357

39,8207725, 30,5358357

B.2 Scenario 2

Before flight:

Time	*Action*	*Responsibility*	*Message*
	Drone airspace allocated	ATC	fact-test/atc/airspace
	GA area allocated	ATC	fact-test/atc/airspace
	Free flight request submittal	Drone operator	fact-test/gcs/free_flight_request
	Free flight request approval	ATC	fact-test/utm/approval

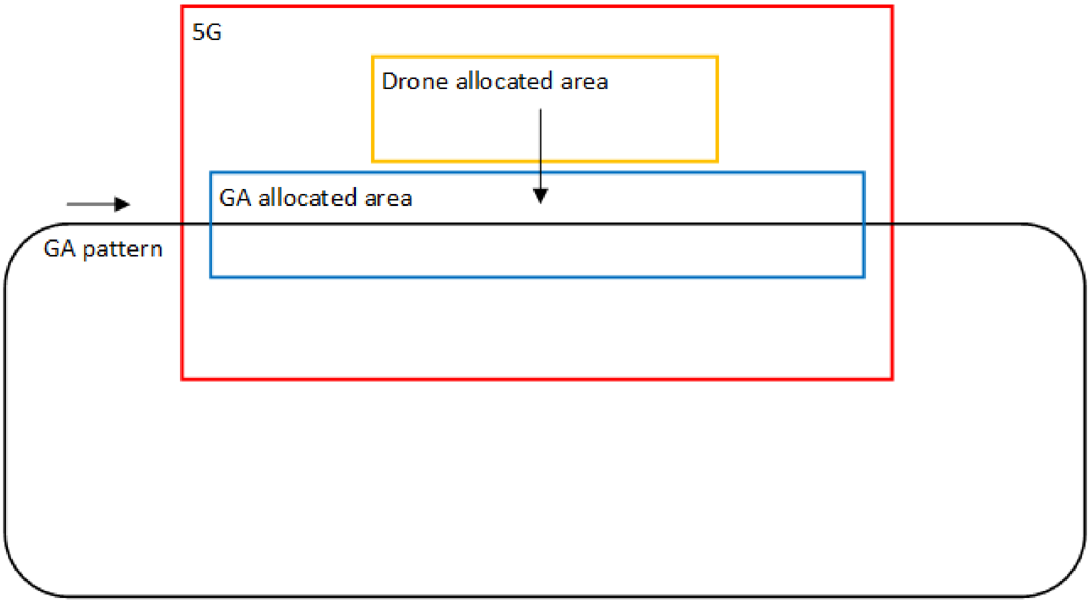
Flight

Time	*Action*	*Responsibility*	*Message*
T0-720 seconds	Engine start-up	ESTU	
T0-420	Request taxi from ATC	ESTU	
T0-390	Starting taxi from ATC	ESTU	
T0-90	Holding Point	ESTU	
T0-30	Permission for take-off from ATC	ESTU	
T0	Line-up and take-off clearance Cessna starts to perform its flight pattern at 2600 feet SL (Sea Level) (0 Feet AGL (Above Ground Level)) altitude defined by dimensions of (4345 x 11781) feet and corner coordinates (39°48'32.88N, 30°32'29.04"E) Corner-1 for Cessna, (39°48'36.63"N, 30°29'53.76"E) Corner-2 for Cessna,	ESTU	

	(39°49'20.21"N, 30°30'18.06"E) Corner-3 for Cessna, (39°49'24.22"N, 30°31'23.90"E) Corner-4 for Cessna. (39°48'55.54"N, 30°32'38.43"E) Corner-5 for Cessna.		
T0+120	Cessna passes through corner-coordinate 2 (39°48'36.63"N, 30°29'53.76"E) and begins to crosswind flight pattern at 3250 feet SL (650 feet AGL) altitude.	ESTU	
T0+180	Cessna passes through corner-coordinate 3 (39°49'20.21"N, 30°30'18.06E) begins to downwind flight pattern at 3250 feet SL (650 feet AGL) altitude.	ESTU	
T0 + 200	Drone B starts to perform its flight pattern at 2600 (0 Feet AGL) feet. The corner coordinates for Drone B (39°49'8.43"N, 30°32'23.74"E) Corner-1 for DroneB, (39°49'20.43"N, 30°31'53.19"E) Corner-2 for DroneB, (39°49'31.17"N, 30°32'2.32"E) Corner-3 for DroneB (39°49'19.52"N, 30°32'29.05"E) Corner-4 for DroneB.	ITU	-
T0 + 220	The drone B reaches 2750 feet SL (150 feet AGL) for its flight pattern and starts to perform its trajectory defined by sequence of points 1. 39°49'20.65"N, 30°31'56.01"E Starting point 2. 39°49'16.27"N, 30°32'7.49"E 3. 39°49'12.62"N, 30°32'6.35"E 4. 39°49'13.18"N, 30°32'11.37"E	ITU	

	5. 39°49'13.42"N, 30°32'14.39"E 6. 39°49'27.15"N, 30°32'3.12"E 7. 39°49'21.98"N, 30°31'56.79"E		
T0+222	Cessna passes through corner-coordinate 4 (39°49'24.22"N, 30°31'23.90"E) continues to downwind flight pattern at 3250 feet SL (650 feet AGL) altitude.	ESTU	
T0 + 232	Cessna enters its allocated area at given coordinates that are 39°49'18.60"N, 30°31'38.73"E • Cessna passes through its allocated area in 34 seconds (blue rectangular area).	ESTU	
T0 + 245	Drone B enters Cessna area at given coordinates that is 39°49'13.46"N, 30°32'6.60"E •	ITU	
T0 + 246	Alert message is provided by UTM. Exp. CNS device forwards this message to drone.	**Automated action (UTM)**	fact-test/UAV/D0000B/alert
T0 + 246	UTM produces message forcing drone to land	**Automated action (UTM)/HON**	fact-test/utm/dronetoland
T0 + 247	Experimental CNS device on drone B send the message forcing drone to land to drone B FCC	**Automated action (UTM)**	fact-test/drone-cns/dronetoland
T0 + 247	GA pilot is informed about alert by Situational Awareness application (and by VHF voice as safety check ?)	ESTU	-
T0+247	GA pilot informs ATC and starts to perform avoidance manoeuvre.	ESTU	-
T0+250	(39°49'8.07"N, 30°32'5.47"E) is the nearest coordinate to the coordinate from which the drone exited its geocage. This coordinate is on the flight pattern of the Cessna.	ESTU	

	Drone lands. WhatsApp call about successful / not successful run. If first attempt was successful, Cessna lands. If first attempt was not successful, Cessna continues in performing flight pattern and drone will start again from start point. All participants will be informed about next drone start.	HON	



GA allocated area:

39,8237789N, 30,5336815

39,8231989N, 30,531213E

39,8184175N, 30,5360727E

39,8184175N, 30,5360727E

Drone allocated area:

39,8190095N, 30,5399274E

39,8223405N, 30,5314427E

39,825325N, 30,5339778E

39,8220889N, 30,5414028E

B.3 Scenario 3

Before flight:

Time	*Action*	*Responsibility*	*Message*
	Drone A trajectory approved	ITU	fact-test/UAV/D0000A/trajectory
	Drone B trajectory approved	ITU	fact-test/UAV/D0000B/trajectory
	Approved trajectories for drones visible in SA applications	HON, ESTU	-

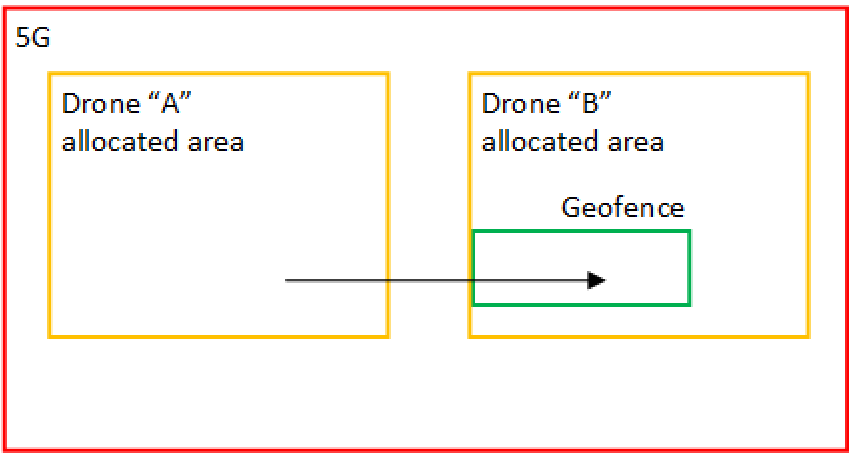
Flight

Time	*Action*	*Responsibility*	*Message*
T0	Drone A starts to perform its flight pattern at 2600 (0 Feet AGL) feet and the corner coordinates for DroneA (39°49'8.62"N, 39°49'8.62"E) Corner-1 for DroneA, (39°49'15.36"N, 30°31'48.83"E) Corner-2 for DroneA, (39°49'31.17"N, 30°32'2.32"E) Corner-3 for DroneA, (39°49'25.80"N, 30°32'12.94"E) Corner-4 for DroneA.	ITU	-
T0	Drone B starts to perform its flight pattern at 2600 (0 Feet AGL) feet and the corner coordinates for DroneB (39°48'57.18" N, 30°32'20.35"E) Corner-1 for DroneB, (39°49'8.24"N, 30°32'1.78"E) Corner-2 for DroneB, (39°49'25.18"N, 30°32'13.66"E) Corner-3 for DroneB (39°49'19.65"N, 30°32'26.35"E) Corner-4 for DroneB.	ITU	-

T0 + 20	The drone A reaches 2680 feet SL (80 feet AGL) for its flight pattern and starts to perform its trajectory defined by sequence of points 1. 39°49'14.17"N, 30°31'55.20"E Starting point 2. 39°49'18.04"N, 30°31'53.88"E 3. 39°49'21.05"N, 30°31'57.62"E 4. 39°49'23.09"N, 30°32'3.26"E 5. 39°49'18.33"N, 30°32'5.99"E 6. 39°49'16.65"N, 30°32'9.01"E 7. 39°49'23.74"N, 30°32'10.25"E 8. 39°49'13.79"N, 30°31'55.76"E	ITU	
T0 + 25	The drone B reaches 2780 feet SL (180 feet AGL) for its flight pattern and starts to perform its trajectory defined by sequence of points 1. 39°49'8.11"N, 30°32'4.15"E 2. 39°49'9.10"N, 30°32'11.26"E 3. 39°49'14.51"N, 30°32'14.25"E 4. 39°49'16.70"N, 30°32'19.41"E 5. 39°49'14.12"N, 30°32'20.04"E 6. 39°49'7.45"N, 30°32'12.64"E 7. 39°49'3.84"N, 30°32'14.26"E 8. 39°49'12.51"N, 30°32'22.82"E 9. 39°49'1.52"N, 30°32'19.89"E 10. 39°49'2.31"N, 30°32'14.94"E 11. 39°49'6.88"N, 30°32'4.91"E	ITU	
T0 + 60	Drone A starts to deviate from corridor at given coordinates (39°49'17.51"N, 39°49'17.51"E)	ITU	-
T0 + 61	Alert message is provided	**Automated action (UTM)**	fact-test/UAV/D0000A/alert
T0 + 62	Geocage zone is deployed with dimensions (800 x 1300) feet and corner coordinates* (39°48'58.10"N, 30°32'20.24"E) Geocage C-1 for Drone B (39°49'7.11"N, 30°32'5.56"E) Geocage C-2 for Drone B	**Automated action (UTM)/HON**	fact-test/utm/geofence

	(39°49'14.00"N, 30°32'10.41"E) Geocage C-3 for Drone B (30°32'10.41"N, 30°32'22.55"E) Geocage C-4 for Drone B		
T0 + 62	Drone A continues its flight in original corridor	ITU	-
T0 + 63	Drone operator via GCS changes flight plan for drone B to avoid geofence and provides it to USSP	ITU	fact-test/gcs/flight_trajectory/1
T0 + 64	UTM checks new flight plan and approves it.	**Automated action (UTM)**	fact-test/utm/flight_trajectory/1/reply
T0 + 65	Drone operator conducts flight per new approved flight plan	ITU	-
T0 + 65	UTM cancels geofence	**Automated action (UTM)/HON**	fact-test/utm/geofence (empty message)
	WhatsApp call about result of first attempt. Even it was not successful, drones land and scenario will start again.		

***Geofence zone is predefined to intervene to drone B trajectory**



Co-funded by the European Union

B.4 Scenario 4

Before flight:

Time	*Action*	*Responsibility*	*Message*
	Drone airspace allocated	ATC	fact-test/atc/airspace
	GA area allocated	ATC	fact-test/atc/airspace
	Free flight requests submittal for drone A	Drone operator	fact-test/gcs/free_flight_request
	Free flight request approval for drone A	ATC	fact-test/utm/approval

Participants: Drone A, helicopter

Flight

Time	*Action*	*Responsibility*	*Message*
T0-720 seconds	Engine start-up	SARP	
T0-420	Request taxi from ATC	SARP	
T0-390	Starting taxi from ATC	SARP	
T0-90	Holding Point	SARP	
T0-30	Permission for take-off from ATC	SARP	
T0	Line-up and take-off clearance Helicopter starts to perform its flight pattern at 2600 feet SL (Sea Level) (0 Feet AGL (Above Ground Level)) altitude defined by dimensions of (4345 x 11781) feet and corner coordinates	SARP	

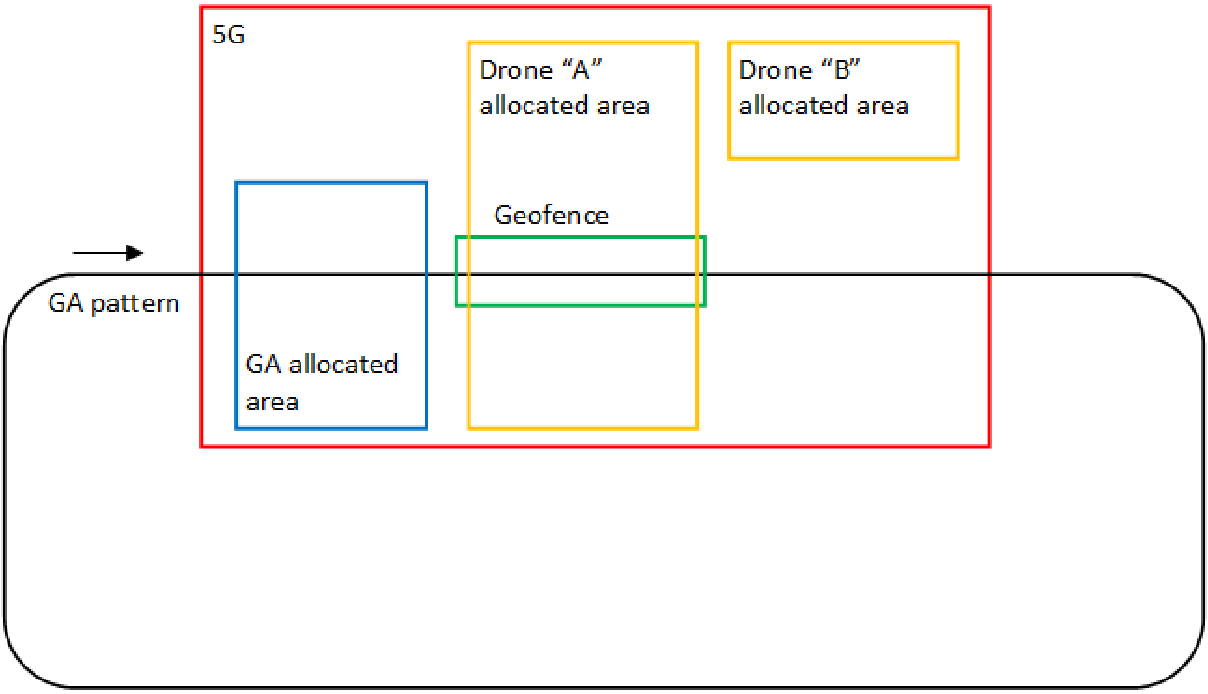
	(39°48'32.88N, 30°32'29.04"E) Corner-1 for heli, (39°48'36.63"N, 30°29'53.76"E) Corner-2 for heli, (39°49'20.21"N, 30°30'18.06"E) Corner-3 for heli, (39°49'35.06"N, 30°31'15.60"E) Corner-4 for heli. (39°48'55.54"N, 30°32'38.43"E) Corner-5 for heli.		
T0+120	Helicopter passes through corner-coordinate 2 (39°48'36.63"N, 30°29'53.76"E) and begins to crosswind flight pattern at 3250 feet SL (650 feet AGL) altitude.	SARP	
T0+180	Helicopter passes through corner-coordinate 3 (39°49'20.21"N, 30°30'18.06E) begins to downwind flight pattern at 3250 feet SL (650 feet AGL) altitude.	SARP	
T0 + 200	Drone A starts to perform its flight pattern at 2600 (0 Feet AGL) feet. The corner coordinates for Drone A are (39°49'6.12"N, 30°32'4.38"E) Corner-1 for Drone A, (39°49'14.71"N, 30°31'49.41"E) Corner-2 for Drone A, (39°49'31.17"N, 30°32'2.32"E) Corner-3 for Drone A, (39°49'23.66"N, 30°32'16.93"E) Corner-4 for Drone A.	ITU	-
T0+205	Drone B starts to perform its flight pattern at 2600 (0 Feet AGL) feet. The corner coordinates for Drone B are (39°49'6.16" N, 30°32'22.36"E) Corner-1 for Drone B, (39°49'11.99"N, 30°32'11.82"E) Corner-2 for Drone B,	ITU	

	(39°49'22.68"N, 30°32'18.93"E) Corner-3 for Drone B (39°49'18.46"N, 30°32'27.65"E) Corner-4 for Drone B.		
T0+216	Helicopter passes through corner-coordinate 4 (39°49'24.22"N, 30°31'23.90"E) continues to downwind flight pattern at 3250 feet SL (650 feet AGL) altitude.	SARP	
T0 + 220	The drone A reaches 2750 feet SL (150 feet AGL) for its flight pattern and starts to perform its trajectory defined by sequence of points 1. 39°49'20.65"N, 30°31'56.01"E Starting point 2. 39°49'16.27"N, 30°32'7.49"E 3. 39°49'12.62"N, 30°32'6.35"E 4. 39°49'13.18"N, 30°32'11.37"E 5. 39°49'13.42"N, 30°32'14.39"E 6. 39°49'27.15"N, 30°32'3.12"E 7. 39°49'21.98"N, 30°31'56.79"E	ITU	
T0+225	The drone B reaches 2750 feet SL (150 feet AGL) for its flight pattern and starts to perform its trajectory defined by sequence of points 1. 39°49'7.56"N, 30°32'20.87"E Starting point 2. 39°49'11.73"N, 30°32'13.05"E 3. 39°49'18.39"N, 30°32'17.21"E 4. 39°49'15.04"N, 30°32'24.94"E 5. 39°49'14.32"N, 30°32'16.76"E 6. 39°49'8.16"N, 30°32'21.29"E	ITU	
T0 + 242	Helicopter enters drone A’s allocated area from coordinates that is 39°49'18.36"N, 30°31'52.30"E • Helicopter passes through drone A’s allocated area in 11 seconds.	SARP	

	Vertical separation between drone A and helicopter will be at least 500 ft and will be maintained during whole scenario.		
T0 + 243	ATC detects violation of drone are by situational awareness application.	ATC	-
T0 + 244	ATC provides message requiring geofence to UTM	ATC	fact-test/atc/geofence
T0 + 244	ATC provides voice instruction to helicopter pilot	**ATC**	-
T0 + 243	Geofence zone is deployed with dimensions (1265 x990) feet and corner coordinates * (39° 49' 30.1224'' N, 30° 32' 3.21'' E**) Geocage C-1 for Drone A and Drone B** (39° 49' 21.0108'' N, 30° 31' 54.2496'' E) Geocage C-2 for Drone A and Drone B (39° 49' 6.5352'' N, 30° 32' 22.1352'' E) Geocage C-3 for Drone A and Drone B (39° 49' 18.9228'' N, 30° 32' 26.6136'' E) Geocage C-4 for Drone A and Drone B	**Automated action (UTM)/HON**	fact-test/utm/geofence
T0 + 243	Drone A and drone B change its flights to avoid geofence	ITU	fact-test/gcs/flightplan/1
T0 + 245	UTM checks new flight plan and approves it.	**Automated action (UTM)**	fact-test/utm/flightplan/1/reply
T0 + 250	Drone A and B start to perform new trajectories.		
	WhatsApp call if first attempt was successful. If not, helicopter continues in its flight patterns, drone will land and start again. Participants will be informed about time of start by WhatsApp call.	**HON / ITU**	

1) **Mitigation action: ATC informs drone operator by (*VoIP voice)* if necessary (one drone is too close, no time for reacting to geofence – emergency situation)**

2) **If drone operator does not react in predefined time, drone is forced to land by ATC (ATC to USSP, USS P to drone CNS dev.)**



B.5 Scenario 5

Before flight:

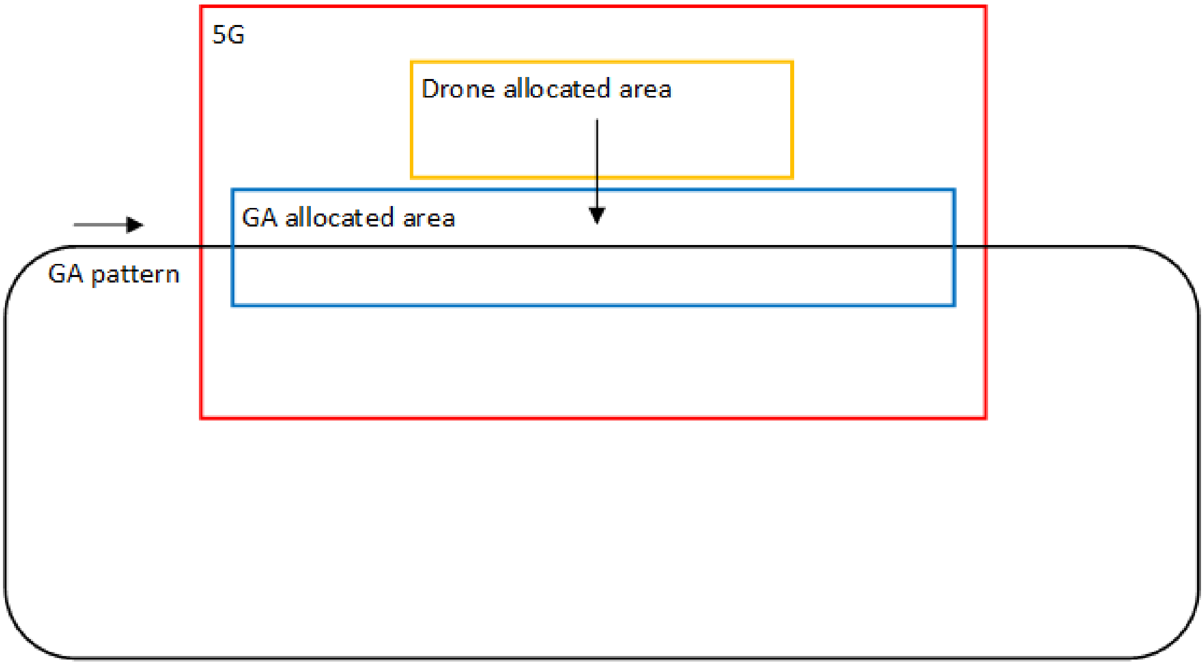
Time	*Action*	*Responsibility*	*Message*
	Drone airspace allocated	ATC	fact-test/atc/airspace
	GA area allocated	ATC	fact-test/atc/airspace
	Free flight requests submittal for both drones	Drone operator	fact-test/gcs/free_flight_request
	Free flight request approval for both drones	ATC	fact-test/utm/approval

Flight

Time	*Action*	*Responsibility*	*Message*
T0-720 seconds	Engine start-up	SARP	
T0-420	Request taxi from ATC	SARP	
T0-390	Starting taxi from ATC	SARP	
T0-90	Holding Point	SARP	
T0-30	Permission for take-off from ATC	SARP	
T0	Line-up and take-off clearance	SARP	

	Helicopter starts to perform its flight pattern at 2600 feet SL (Sea Level) (0 Feet AGL (Above Ground Level)) altitude defined by dimensions of (4345 x 11781) feet and corner coordinates (39°48'32.88N, 30°32'29.04"E) Corner-1 for heli, (39°48'36.63"N, 30°29'53.76"E) Corner-2 for heli, (39°49'20.21"N, 30°30'18.06"E) Corner-3 for heli, (39°49'24.22"N, 30°31'23.90"E) Corner-4 for heli. (39°48'55.54"N, 30°32'38.43"E) Corner-5 for heli.		
T0+120	Helicopter passes through corner-coordinate 2 (39°48'36.63"N, 30°29'53.76"E) and begins to crosswind flight pattern at 3250 feet SL (650 feet AGL) altitude.	SARP	
T0+180	Helicopter passes through corner-coordinate 3 (39°49'20.21"N, 30°30'18.06E) begins to downwind flight pattern at 3250 feet SL (650 feet AGL) altitude.	SARP	
T0 + 200	Drone B starts to perform its flight pattern at 2600 (0 Feet AGL) feet and the corner coordinates for Drone B are (39°49'8.43"N, 30°32'23.74"E) Corner-1 for Drone B, (39°49'20.43"N, 30°31'53.19"E) Corner-2 for Drone B, (39°49'31.17"N, 30°32'2.32"E) Corner-3 for Drone B, (39°49'19.52"N, 30°32'29.05"E) Corner-4 for Drone B.	ITU	-
T0 + 215	The drone B reaches 2750 feet SL (150 feet AGL) for its flight pattern and starts to perform its trajectory defined by sequence of points	ITU	

	1. 39°49'7.56"N, 30°32'20.87"E Starting point 2. 39°49'15.69"N, 30°32'7.18"E 3. 39°49'12.75"N, 30°32'6.22"E 4. 39°49'14.53"N, 30°32'14.92"E 5. 39°49'23.93"N, 30°32'1.64"E 6. 39°49'21.42"N, 30°31'56.75"E		
T0+220	Helicopter passes through corner-coordinate 4 (39°49'24.22"N, 30°31'23.90"E) continues to downwind flight pattern at 3250 feet SL (650 feet AGL) altitude.	SARP	
T0 + 240	Drone B enters helicopter's allocated area at given coordinates (39°49'13.46"N, 30°32'6.60"E). Helicopter passes through its allocated area in 56 seconds (blue rectangular area).		
T0 + 241	Alert message is provided	**Automated action (UTM)**	fact-test/UAV/D0000B/alert
T0 + 242	ATC is informed about alert by Situational Awareness Application. ATC alerts and instructs helicopter pilot by voice	ATC	-
T+242	Drone operator controls drone back to its airspace	ITU	-
T0+247	(39°49'8.74"N, 30°32'4.44"E) is the nearest coordinate to the coordinate from which the drone exited its geocage. This coordinate is on the flight pattern of the helicopter.	SARP	
	WhatsApp call about first attempt result. If it was successful, drone lands, helicopter lands. If not, helicopter continues in its flight pattern. Drone lands and starts again. Participants will be informed about next start.	HON/ITU	


5G
Drone allocated area
GA allocated area
GA pattern