Validation Plan

Deliverable ID:	**D5.1**
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:	**26th November 2021**
Edition:	**00.01.01**
Template Edition:	**02.00.02**

Founding Members
EUROPEAN UNION
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00.00.09	29/09/2021	Haluk Yapıcıoğlu
00.00.09	29/09/2021	Birsen Açıkel
00.00.10	29/09/2021	Klaus Peter Sternemann
00.00.10	29/09/2021	Petr Casek
00.00.11	30/09/2021	İlkay Orhan
00.00.11	30/09/2021	Uğur Turhan
00.00.11	30/09/2021	Haluk Yapıcıoğlu
00.01.00	30/09/2021	Birsen Açıkel
00.01.01	26/11/2021	Haluk Yapıcıoğlu

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FACT

FUTURE ALL AVIATION CNS TECHNOLOGY

This Validation Plan 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 represents validation planning activities and studies for the FACT project. It describes validation activities, execution plans and contents within the consortium and operational environment and defines generic scenarios depending on the project use cases which will be improved during project work.

The validation preparation task has been carried out simultaneously to most of the previous project tasks. The information about scenarios that will be simulated and validated, generic validation plan, validation risk management plan and validation expected outcomes will be presented.

Table of Contents

List of Figures

List of Tables

1 Executive Summary

This document is prepared in order to present the details of the validation process which will take place at Eskisehir Technical University, Eskisehir Turkey with important contributions from Honeywell, Nokia, ITU, Sarp Air, AOPA and Eurocontrol. Validation process is an essential part of the FACT project, through which capabilities of the tracking device being developed will be tested using 5G communication technologies at the premises of ESTU using both Aerodrome Control Simulator and in controlled/uncontrolled airspaces.

The validation preparation task has been carried out simultaneously to most of the previous project tasks. The information about scenarios that will be simulated and validated, generic validation plan, validation risk management plan and validation expected outcomes will be presented.

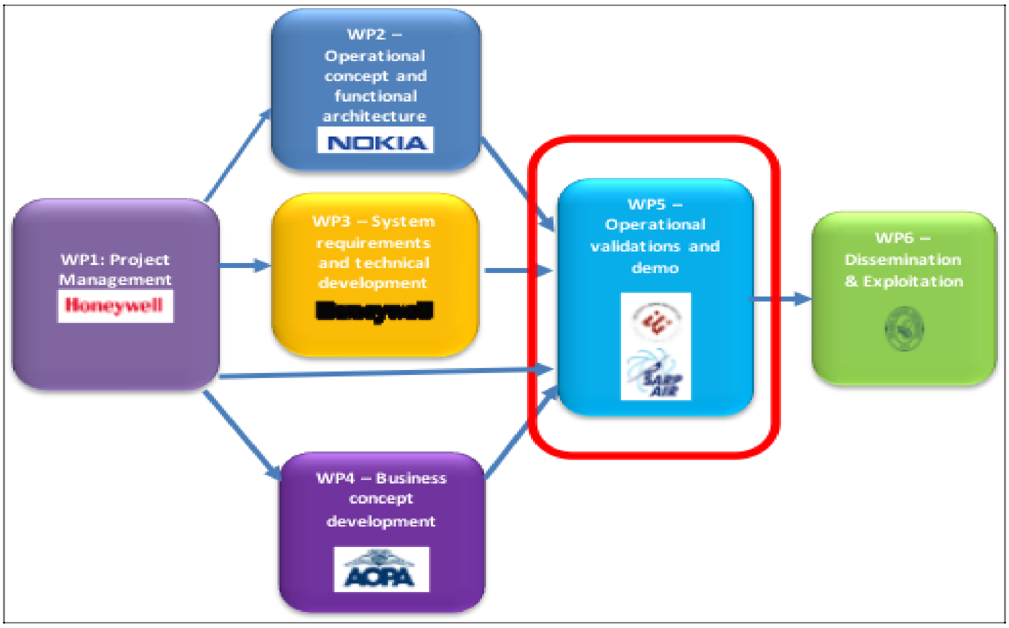


Figure 1. Relationship among the validation work package **and the other WPs**

Validation activities are divided into two major studies: (1) simulations to be completed using the Aerodrome Control Simulator, and (2) tests to be performed with the participation of GA aircrafts and drones. From the operational safety perspective, all scenarios first will be run in the Aerodrome Control Simulator. As the output of this first validation activity, contribution of the tracking device to operational safety and situational awareness will be assessed. In addition, project team will also be able to assess the scenarios from flight safety perspective and make necessary changes to the scenarios in the presence of high-risk situations observed during the simulations. As a result, scenarios for the second validation activities can be modified to minimize/mitigate risks observed during the first validation. Execution of the first validation activities are planned to be completed by the end of 2021 and the second validation activities will be concluded in June and July 2022[1]. Detailed plan will be prepared by January 2022 and agreed with SJU at the progress meeting.

In this document, we first start by introduction and purpose of the document in Section 1. Acronyms and terminology used throughout the document also provided in this section. Next, scope of validation activities, validation activities plan and expected outcomes are presented in detail in Section 3. Validation use cases (detailed scenarios) and overall structure of the scenarios are also in Section 3. Platforms that will be used in validation activities are reported in Section 4, organized by project partners.

An essential part of any validation activity is the Risk Management Plan, especially in aviation sector. To this end, Section 5 is dedicated to the risk management plan of validation activities. Inputs provided from the partners of the project consortium are consolidated to a comprehensive risk management plan along with anticipated risk mitigation measures. Document concludes with the references and annex section.

[1] While the main technical activities are planned to be concluded by end of June 2022, due to the operational reasons, the operational demo at Eskisehir airport won't be possible to start sooner than in second half of June, and therefore it is expected that the demo will be partially executed also in July (mainly a dissemination part of this activity).

2 Introduction

2.1 Purpose of this Document

This document provides detailed information regarding the two validation activities foreseen within the FACT project.

It is developed within WP5, Task T5.1. It is the reference document that will be used to organize and manage the validation activities. Relationships among project tasks can be summarized as in Figure 2 below:

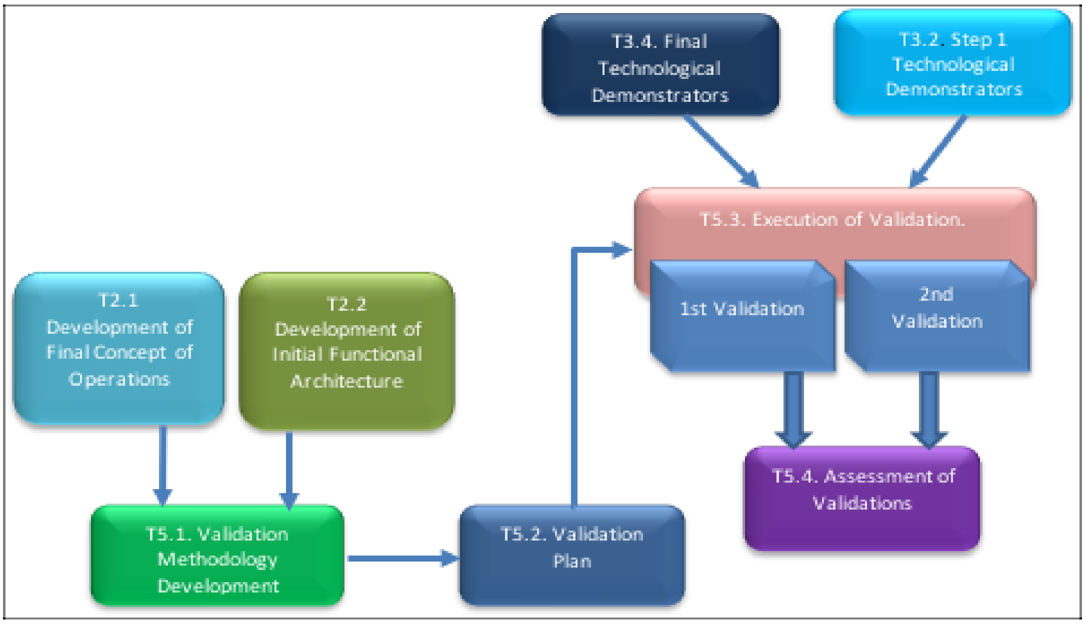


Figure 2. Relationship among T5.2 Validation Plan and other technical tasks of the project

This document builds upon several other tasks completed within the scope of the project. More specifically, the document takes input from:

- The results of the development of final concept of operations (T2.1),
- The results of the development of initial functional architecture (T2.2), and,
- The preliminary results of the validation methodology development activities (T5.1)

in order to generate the planning for the two validations and related objectives, scenarios, validation methods, risk management plan, expected outcomes.

2.2 Deliverable Structure

In this document, we first start by introduction and purpose of the document in Section 1. Acronyms and terminology used throughout the document also provided in this section. Next, scope of validation activities, validation activities plan and expected outcomes are presented in detail in Section 3. Validation use cases (detailed scenarios) and overall structure of the scenarios are also in Section 3.

Platforms that will be used in validation activities are reported in Section 4, organized by project partners.

An essential part of any validation activity is the Risk Management Plan, especially in aviation sector. To this end, Section 5 is dedicated to the risk management plan of validation activities. Inputs provided from the partners of the project consortium are consolidated to a comprehensive risk management plan along with anticipated risk mitigation measures. Document concludes with the references and annex section.

2.3 Acronyms and Terminology

Acronyms and the terminology used throughout the report can be summarized as below:

Term	Definition
ABIL	AirScale Baseband Extension Sub-Module
AFIS	Aerodrome Flight Information Service
AIP	Aeronautical Information Publication
AMF	Access and Mobility Management Function
AMSL	Above Mean Sea Level
ANSP	Air Navigation Service Provider
AOE	Eskişehir Hasan Polatkan Airport
ASIK	AirScale System Module Indoor Version K
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
ATPL	Airline Transport Pilot Licence
ATSEP	Air Traffic Safety Electronics Personnel
AUSF	Authentication Server Function
CAA	Civil Aviation Authority
CIS	Common Information Sharing service
CNS	Communications, Navigation and Surveillance Systems
DHMI	Devlet Hava Meydanları İşletmesi(The Directorate General of Civil Aviation)
DME	Distance-Measuring Equipment
EASA	European Aviation Safety Agency
EPC	Evolved Packet Core
ESTU	Eskisehir Technical University
FAB	Fast Airport Builder
FACT	Future All Aviation CNS Technology
GA	General Aviation
GE	Gigabit Ethernet
HW	Hardware
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
LTBY	Hasan Polatkan International Airport
MIMO	Multiple-Input and Multiple-Output
mMTC	massive Machine-Type Communication

NDB	Non-directional Beacon
NF	Network functions
NG-RAN	Next Generation Radio Access Network
NM	Nautical Mile
NRF	Network Repository Function
NSA	Non-Stand-Alone
PPL	Private Pilot Licence
RAN	Radio Access Network
RAPCON	Radar Approach Control System
RF	Radio Frequency
RRH	Remote Radio Heads
SA	Stand-Alone
SBI	Service Based Interfaces
SESAR	Single European Sky ATM Research (the programme which defines the Research and Development activities and Projects within Europe)
SMF	Session Management Function
URLLC	Ultra Reliable Low Latency Communication
UDM	Unified Data Management
UDR	Unified Data Repository (not shown in the figure above)
UPF	User Plane Function
VLAN	Virtual Local Area Network
VOR	VHF Omni-directional Radio Range

3 Context of the Validation

3.1 Scope of Validation Activities

During the FACT validation activities, the iCNS concept will be validated both in controlled airspace (airport) with ATM infrastructure, and uncontrolled airspace with very limited ATM support. The main project achievements will be demonstrated during the flight demo in Eskisehir airport area (Turkey).

The high-level validation objectives of the FACT are:

- Technical Validation of CNS performance (feasibility): datalink & positioning using cellular network (4G/5G) – both public and dedicated – complementing current aero technologies.
- Demonstration of benefits due to CNS enhancements: Improved situational awareness of GA pilots, drone remote pilots, ATCO.

The FACT plans to perform validation activities in two steps: first and second validation. The aim of the first validation to create appropriate setup for the real site combined validation which is second validation will be performed in ESTU, Eskisehir (Turkey) airport and its proximity with mixed GA and drones' operations within experimental 5G network.

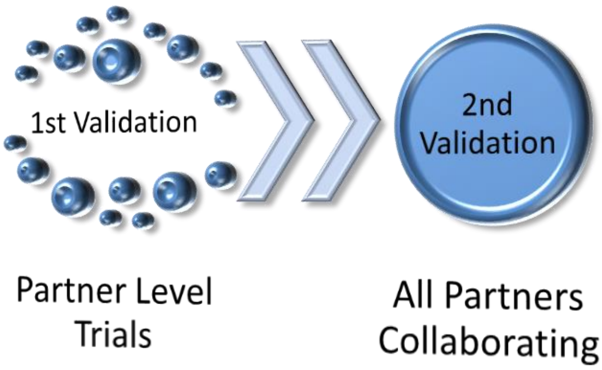


Figure 3. FACT Validation levels

The first validation will be creating base setup to support the second validation for each project partner who will be taking role in the operational trial to reach expected outcomes of the project.

3.2 Validation Objectives

The high-level validation goals described in the previous section can be decomposed into the following set of validation objectives:

Objective	Rationale	Success Criteria
OBJ-1: Validate that the performance of cellular network is capable to support ground traffic surveillance based on air → ground position reporting.	Within the operational demo, the focus will be on evaluation of communication performance – therefore the success criteria are related to REQ-PERF-2-1 of D3.1 complemented with some additional criteria derived from ADS-B traffic tracker[2] requirements.	SUCC-1-1: The 95% total latency of the position reports (between aircraft transmission to ground tracker) won't be greater than 0.5s.
		SUCC-1-2: Update rate at the ground tracker (reception of the new position report) will be less than 3s (99% of time).
		SUCC-1-3: No tracks within the range of demo's operational area will be dropped by the ground tracker due to missing position reports.
OBJ-2: Validate that the performance of cellular network is capable to support traffic information services (ground → air) contributing to airborne situation awareness and detect and avoid functions.	Within the operational demo, the focus will be on evaluation of communication performance – therefore the success criteria are related to REQ-PERF-1-5 of D3.1 complemented with some additional criteria derived from airborne applications requirements.	SUCC-2-1: The 95% total latency of the position information about an aircraft (between reception of its position report by ground tracker to reception of TIS message by airborne users) won't be greater than 1s.
		SUCC-2-2: Update rate of the airborne traffic tracker using TIS data (reception of the new position report) will

[2] The generic ADS-B tracker as described in EUROCAE ED-194B (July 2020) is used as a reference.

		be less than 5s (99% of time).
		SUCC-2-3: No tracks within the range of demo's operational area will be dropped by the airborne tracker due to missing TIS position reports.
OBJ-3: Validate that the performance of cellular network is capable to support alerting messages communicated by ATM/UTM services (ground → air).	Within the operational demo, the focus will be on evaluation of communication performance – therefore the success criteria are related to requirements listed in section 5.3 of D3.1 (namely G2A ATS dedicated communication mode)	SUCC-3-1: The 95% total latency of the alerting message sent by ground services to a flying vehicle won't be greater than 0.5s.
		SUCC-3-2: Maximum latency of the alerting message sent by ground services to a flying vehicle won't be greater than 5s.
OBJ-4: Validate that the tested applications enabled by cellular network infrastructure improve overall operational safety	As the amount of data which will be possible to collect during the operational demo won't allow to perform rigorous quantitative safety analysis, the success criteria are based on evaluating feedback of stakeholders/users involved in the demo.	SUCC-4-1: Positive feedback from ATC controller based on questionnaires and workshop discussions processed after/during demo operations.
		SUCC-4-2: Positive feedback from drones' remote pilots based on questionnaires and workshop discussions processed after/during demo operations.
		SUCC-4-3: Positive feedback from GA pilots based on questionnaires and workshop discussions processed after/during demo operations.

3.3 Plan of validation activities

FACT Validation plan is composed of two parts. Table 1 below presents the summarized information per partner per validation. Details of the objectives are provided in the subsequent sections.

Table 1. FACT Validation Plan

Validation Plan		
	1ST Validation	2ND Validation
Objective:	HONEYWELL - To validate: • HW design of the iCNS experimental unit • Available cellular chips and ADS-B In receivers evaluation • Basic blocks of cloud SW functionality – primarily tracking function • Different networks performance characteristics measured by drone in public and trial networks (effects of altitude resulting in interferences and handovers) • Situational awareness application – testing and refining with human factors team	To validate the: • Performance of datalinks • Analyze potential interferences • Load/complexity of the 5G E2E network. • Radio altimeter performance • Qualitative assessment of benefits for remote pilots, GA pilots and ATCO • Measurement of the network performance in ESTU campus • Use cases and scenarios – acceptability, feasibility • Geofencing performance and trajectory performance • Risk/Emergency management • Situational awareness of operators
	NOKIA - To validate: • Validation of the proper integration and pre-configuration of the network	
	ESTU (+SARP AIR) - To validate: • Detailed description of scenarios • Generation of simulation of scenarios • Running scenarios • Testing and refining the scenarios with stakeholders and human factors	
	ITU- To validate: • C2 Link Performance of the drone • Trajectory tracking performance of the drone • Geofencing/geocaging performance of the drone • Urgent landing performance of the drone	
When:	HONEYWELL : 1st Oct-30th Dec 2021 NOKIA: April 22 (2 weeks) ESTU(+SARP AIR): 1st Oct-30th Dec 2021 ITU: 1st Oct-30th Dec 2021	June/July2022
Where:	HONEYWELL: Primarily Brno, Ostrava; Czech Republic NOKIA: Nokia premises	Nokia ESTU campus ground test network Eskisehir Technical University (Turkey)

	ESTU (+SARP AIR): Eskisehir Technical University Aerodrome Control Simulator (Turkey) ITU: ITUARC Örencik UAV Test Field, Istanbul, Turkey	

3.3.1 First validation Plan

During the 1st validation partners who are involved will be performing their validation activities with required equipment, systems and operational stakeholders. The partners defined their validation locations as their own facilities and equipment. 1st validation execution time frames vary depending on the work to be performed and partners involved and are mostly concluded at the end of the 2021 and beginning of the 2022 while 2nd validation will be concluded by operational demo at June/July of 2022. Their validation objectives and other details can be seen in the validation table above.

3.3.2 Second Validation Plan

The execution of the 2nd validation will include all FACT partners and will be at Eskisehir Technical University airspace, aerodrome and campus, Eskisehir-Turkey. The FACT partners will perform collaborated work all together to validate FACT objective to create value added applications in terms of technology and procedures for the overall objectives. 1st validation achievements and other preparations will contribute the success of the 2nd validation. The FACT 2nd validation is planned to be performed in June and July of 2022 at ESTU, Turkey. Details can be seen in the validation table above.

3.4 Validation Metrics in Detail

The ITU standard T-REC-E.800 and ITU T-REC-G.1000 are adopted in this project in order:

- to harmonize the terminology used for each datalink involved in the three following use cases
- to describe the concept of Quality of Service (QoS) from the perspective of the provider and of the user.

ITU T-REC-E.800 defines the different types of QoS, and ITU-T-REC-G.1000 proposes parameters to qualify the level of QoS (see Annex A)

FACT is using the following criteria familiar in aviation communications:

- Availability: parameter that specifies the required probability that an information exchange between the RPS and RPA can be initiated when required.
- Continuity: parameter that specifies the minimum proportion of information exchanges to be completed within the specified Transaction Expiration Time, given that the service was available at the start of the transaction.

- Integrity: parameter that specifies the required probability that an information exchange is completed with no undetected errors.

- Latency: parameter that specifies the maximum time that is allowed for an information exchange to pass one away through the datalink.

- Transaction Expiration time 95 %: parameter that specifies the maximum time for the completion of 95% of any information exchange after which the safe operation may be compromised.

- Security: qualitative and quantitative specifications required to avoid malicious interferences in the transaction.

Scenarios developed for uncontrolled airspace use case are related to the uncontrolled airspace of Class G with defined U-space in part of it. The CIS collects traffic data from both manned aviation and unmanned vehicles and mediates it for both traffic management systems. As described in the Initial Concept of Operations, the precondition for successful USSP-driven deconfliction of GA and drones and conflict management between drones is the reliable surveillance and information sharing.

Datalinks through cellular networks will serve for communication of drone with the U-space Service Provider and for communication of GA aircraft with AFIS (or another ATM entity). Transmitted information will be primarily the own state and position reporting of the considered traffic. In opposite direction, vehicles in air will receive traffic and airspace information from corresponding U-space Service Provider.

As explained in detail in Section 3.4, **scenarios developed for controlled airspace use case** presents an airport terminal area environment with heterogenous traffic and defined U-space in a part of it. Airspace will be dynamically allocated by the Air Traffic Control. In case of urgency, ATC is able to directly communicate with drone operator.

Expected metrics to be considered during validation scenarios are following:

- Quality of Service
    - Evaluation of the value of the parameters of the Quality of Service Requirements (QoSR) to support
        - dynamically allocated airspace
        - strategic and potentially also tactical conflict management
            - Between drones
            - Between drone and GA
            - Between GA and GA
        - voice over IP (feedback from remote pilots) – relevant for Use Case 2
    - Evaluation of the Quality of Service Offered (QoSO) by the available communications service providers
    - Evaluation if the QoSD in meeting the QoSR for the selected QoS parameters
    - Gather information of the Quality of Service Experienced (QoSE) by the users when relevant
- Analysis of impact on

- Remote pilots (increased situational awareness, benefit of supporting flight information)
- GA pilot (increased situational awareness, benefit of supporting flight information)
- ATCO situational awareness,
- CAA and ANSP monitoring and provided reporting data (not-real time)

- Evaluation of on-board positioning capability
  - feasibility of positioning solution
  - Identifying and understanding of factors contributing to positioning performance
  - navigational performance achieved in terms of benefits for users
- Analysis of impact on drones and GA surveillance
- Evaluation of impact on safety (backup navigation information, quality of position reported by ownships)
- Evaluation of impact on flight/operational efficiency

3.5 Validation Use Cases and Scenarios

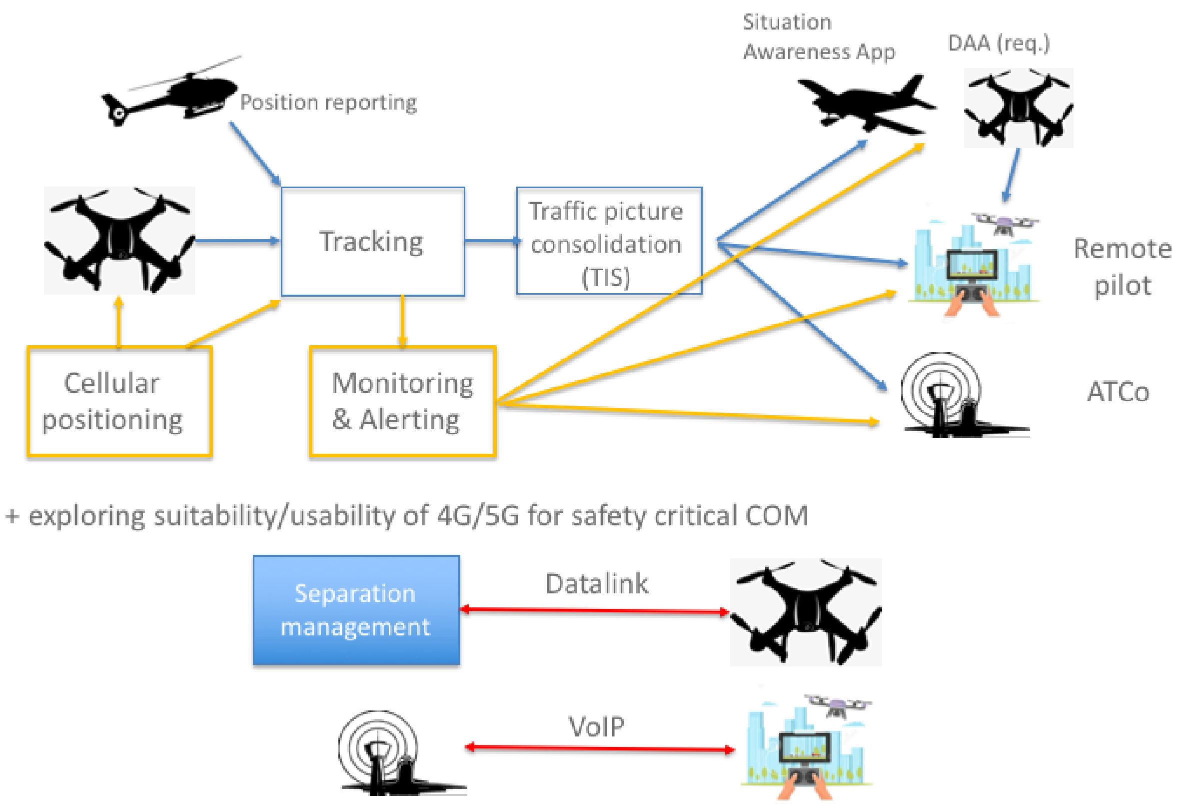


Figure 4. Use case details for 4.5G/5G (D3.1)

The FACT planned use cases to be validated for project works in the uncontrolled and controlled airspaces. The detailed illustration can be seen in the figure above and in D2.1 (Initial ConOps), D2.2 (Initial Functional Architecture) and D3.1 (Technical Enablers and Initial System Requirements) project's deliverables.

3.5.1 Scenario Development Process

Scenarios explained in detail in the next section are developed using inputs from all partners. In doing so, operational safety is the most important consideration. Based on this, the most important contributions were taken from GA pilots and ATCOs. To obtain these contributions several focus group studies have been performed over a month-long period. Based on the information gathered as a result of these focus group studies and the requirements gathered from the project partners, scenarios are developed, and the details of the scenarios are provided next.

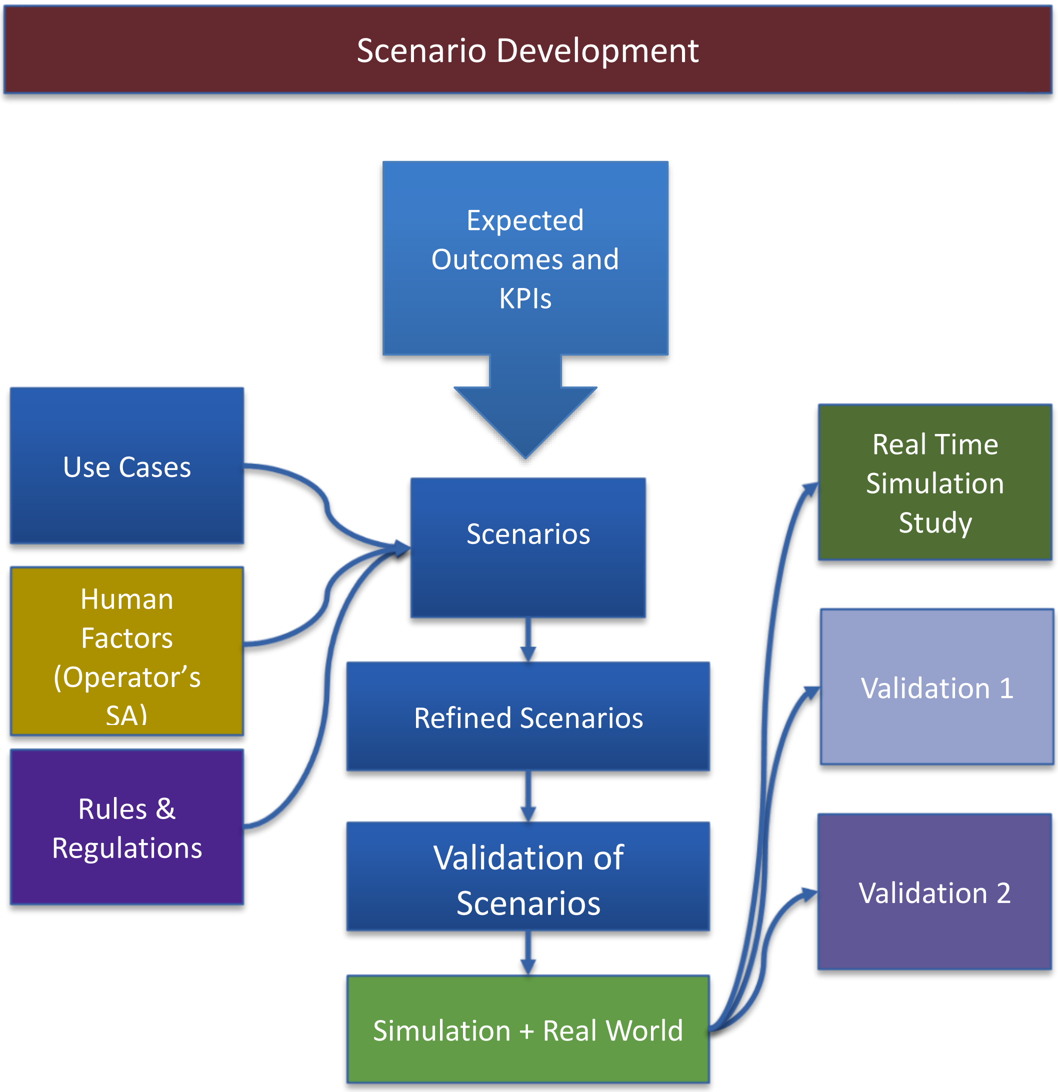


Figure 5. Scenario Development process

The illustration above shows the scenario development process of FACT within consortium members, related stakeholders and literature. The expected outcomes initially defined by considering human factors, use cases, regulations and rules of aviation for the initial development of scenarios. Then in 1st validation, scenarios will be examined in real time simulations and will be matured. During the planned 2nd validation phase, scenarios will be tested for the FACT objectives and improved for the end user expectations.

3.5.2 Scenario Structure

In scenario development, the main objective is to verify that there is a robust and clear communication and data sharing among GA pilots, drone operators and ATCOs to ensure safe and efficient operations so as to increase situational awareness of all operators in shared airspace.

In its broadest sense, scenarios fall into two categories based on whether aircrafts operate in controlled airspace or in uncontrolled airspace. Under each of these categories, there are trajectory-based scenarios and non-trajectory-based scenarios. Both classifications start with a baseline scenario in which there is no conflict among aircrafts including drones. Additional scenarios involve increased complexities such as airspace violations as a result of unexpected situations stemming from the need and/or unknown behaviors of airspace users. A schematic representation of the scenarios is provided in the following Figures 6 and 7, and explained in detail below.

3.5.2.1 Scenarios for uncontrolled airspace Use Case

The scenarios for the uncontrolled airspace can been in the figure 6 below which represents details of the scenario distribution for the trajectory bases.

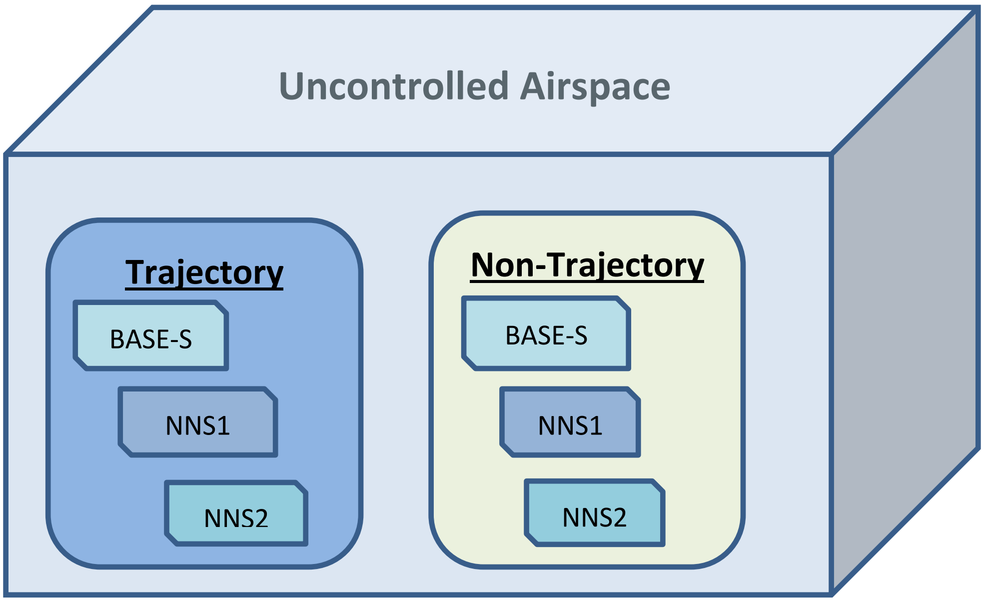


Figure 6. Uncontrolled airspace scenarios

3.5.2.1.1 Non-trajectory based scenarios

Baseline scenario (Base-S) – no trajectory: Reference (baseline) scenario: In the baseline scenario, drones and GA flights are separated in the airspace prior to the beginning of flights. Each and every aircraft including drones fly within their predetermined allocated airspace and they are all visible in SA applications. In the baseline scenario, all flights are to be performed as expected and there will be no conflicts and/or risks posed by overlapping airspaces. All stakeholders are aware of surrounding traffic. The overall objective of the baseline scenario is to assess whether all entities can reliably and continually (without significant delay) provide information on their status to the other stakeholders on essential SA.

Non-Nominal Scenario 1 (NNS1): In this second scenario, the setting is the same as in the baseline scenario however, one of the fixed wings and/or rotorcraft has/have to enter drones' airspace due to unexpected circumstances. When this happens, GA informs ATC, ATC send info to USSP, USSP issues a geofence zone (vertical separation), drone's operator(s) receive info and change flight path to avoid geofence. If the drone operator does not comply within a predefined time period, drone is forced to land safely by appropriate procedures. Based on the ATC's instructions, drone's ground control station (with the drone's operator approval/confirmation) will send "land" command as a drone's C2 message. Consequently, the pre-defined automatic landing operation immediately start with the highest priority.

Non-Nominal Scenario 2 (NNS2): In this scenario the airspace violation is caused by the drone (drones) leaving the allocated airspace, e.g. due to technical difficulties. To avoid conflicts and possible threats to flight safety, USSP issues an alert to GA (for the operational demo purposes we assume a direct communication of the U space service with GA, however the communication can be also mediated by ATM). GA will react based on received information (pilot's decision). In addition, USSP issues a warning to the drone operator as well to make the drone operator to go back to its own geofence.

3.5.2.1.2 Trajectory based scenarios

Base scenario (Base-S): Drones and GA flights strategically de-conflicted by trajectories mainly by vertical separation. Drones are not allowed to fly above a predetermined altitude and GA is not allowed to fly below the altitude set for the drone. This altitude level determined prior to the flights and applies to both drones and GA. Approved trajectories of surrounding traffic available for visualization in SA applications, flights are performed as planned, and all stakeholders are aware of their surrounding traffic. The overall objective of this scenario is the assessment of just feedback on essential SA among users.

Non-Nominal Scenario 1 (NNS1): NNS1 builds upon Base-S and there is a drone which starts to deviate from its approved trajectory. Once the deviating drone is detected, conformance monitoring issues an alert to all users and ATCOs. USSP will first issue a geofence zone until the new trajectory is agreed with the drone's operator, other drones update their trajectories accordingly. Finally, GA maneuver only based on SA info.

Non-Nominal Scenario 2 (NNS2): NNS2 is very similar to NNS1, however conflict resolution is provided by issuing new flight updates/clearances to those users affected by the deviating drone.

3.5.2.2 Scenarios for controlled airspace Use Case

The main difference between scenarios for uncontrolled airspace and scenarios for controlled airspace is that in controlled airspace ATCOs play an active role in conflict resolution. As with usual GA traffic, all drone traffics (in principle) have to comply with the instructions that comes from ATCOs. The scenarios for the controlled airspace can be seen in the figure 7 below which represents details of the scenario distribution for the trajectory bases.

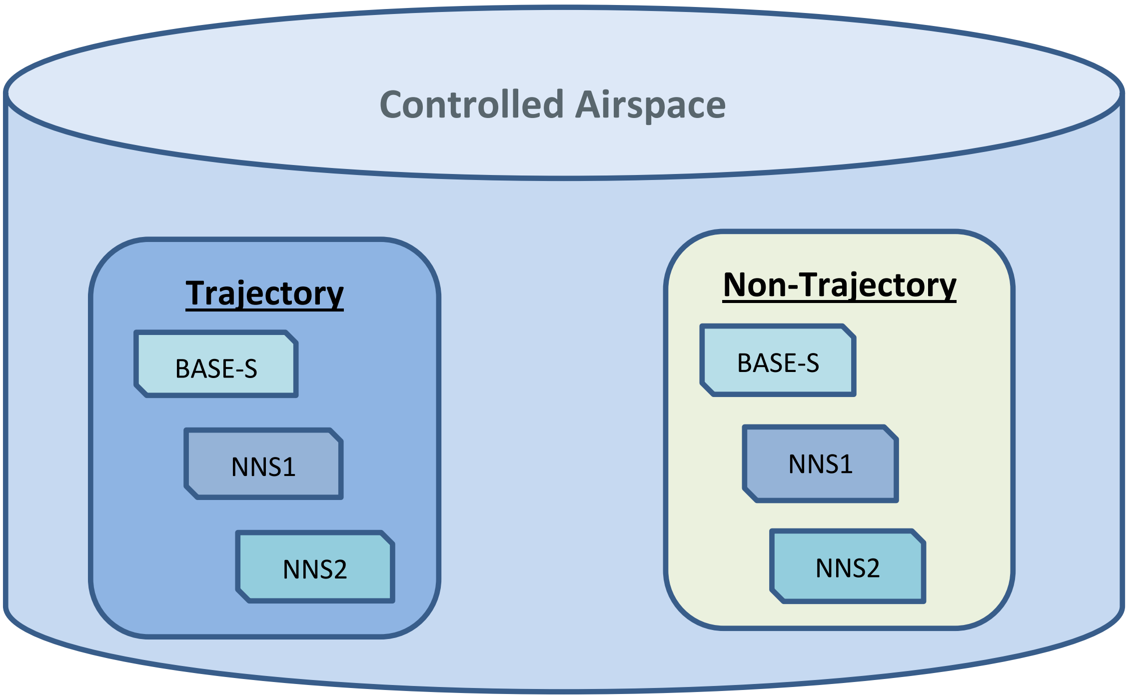


Figure 7. Controlled airspace scenarios

3.5.2.2.1 Non-trajectory based scenarios

Baseline scenario (Base-S): In the baseline scenario, drones and GA flights are separated in the airspace prior to the beginning of flights. Each and every aircraft including drones fly within their predetermined allocated airspace and they are all visible in SA applications. In the baseline scenario, all flights are to be performed as expected and there will be no conflicts and/or risks posed by overlapping airspaces. All users are aware of surrounding traffic and the traffic is monitored by ATCOs. The overall objective of the baseline scenario is to assess whether all entities can reliably and continually (without significant delay) provide information on their status to the stakeholders on essential SA. In addition, additional workload imposed by the drones on ATCOs can also be assessed through these scenarios.

Non-Nominal Scenario 1 (NNS1): In this second scenario, the setting is the same as in the baseline scenario however, one of the fixed wings and/or rotorcraft has/have to enter drones' airspace due to unexpected circumstances. When this happens, the ATCO immediately informs the drone operator concerning the newly established geofence and asks the drone operator to comply. If the drone operator does not comply within a predefined time period, drone is forced to land safely by appropriate procedures. Based on the ATC's instructions, drone's ground control station (with the drone's operator approval/confirmation) will send "land" command as a drone's C2 message. Consequently, the pre-defined automatic landing operation immediately start with the highest priority.

Non-Nominal Scenario 2 (NNS2): In this scenario the airspace violation is caused by the drone (drones) leaving its allocated airspace . To avoid conflicts and possible threats to flight safety, USSP issues an alert to ATCOs, drones and GA. GA will react based on received instructions from ATCOs. In addition, both ATCOs and USSP issues a warning to the drone operator as well to make the drone operator to go back to its own geofence.

3.5.2.2.2 Trajectory based scenarios

Base scenario (Base-S): Drones and GA flights strategically de-conflicted by trajectories mainly by vertical separation as instructed by ATCOs. Drones are not allowed to fly above a predetermined altitude and GA is not allowed to fly below the altitude set for the drone. This altitude level determined prior to the flights and applies to both drones and GA. ATCOs may forbid drones from flying especially when a GA is approaching for landing and/or departing. Approved trajectories of surrounding traffic available for visualization in SA applications, flights are performed as planned, and all stakeholders are aware of their surrounding traffic. The overall objective of this scenario is the assessment of just feedback on essential SA among users.

Non-Nominal Scenario 1 (NNS1): NNS1 builds upon Base-S and there is a drone which starts to deviate from its approved trajectory. Once the deviating drone is detected, conformance monitoring issues an alert to ATCOs and ATCOs issue deconflicting measures to all those affected. ATCOs along with USSP will first issue a geofence zone until the new trajectory is agreed with the drone's operator, other drones update their trajectories accordingly. Finally, GA maneuver only based on ATCOs' instructions

Non-Nominal Scenario 2 (NNS2): NNS2 is very similar to NNS1, however conflict resolution is provided by ATCOs issuing new flight updates to those users affected from the deviating drone.

4 Validation Platforms

4.1 Eskisehir Technical University (ESTU)

The FACT objectives will help the ICAO Global plans and applications to support general aviation safety and efficiency by better monitoring and management of the air traffic including unmanned systems in different categories and cost-efficient integrated solutions. FACT methodology and technological solutions will be developed and tested in ESTU aerodrome control simulation environment and transferred to the real air traffic environment of Hasan Polatkan International Airport (LTBY). ESTU LTBY is a single runway airport with medium sized general and commercial air traffic density and has conventional CNS technologies. The airport and the campus together give a suitable opportunity to realize and test FACT objectives to serve ICAO's plans by focusing on general aviation and unmanned aerial traffic integrated with the other air traffic entities. Besides the airport and airspace potential ESTU will be contributing to the project with educational and research knowledge on aviation and experience by human and technological infrastructure such as aerodrome simulator and its flight training fleet.

Eskisehir Technical University-ESTU (formerly Anadolu University before May 2018) has all scientific disciplines including unique facilities such as the Faculty of Aeronautics and Astronautics and International Airport together. The Faculty of Aeronautics and Astronautics of ESTU is the leading institution in supplying qualified human resources to rapidly growing Turkish Aviation Industry. Since its establishment in 1986, the faculty has been providing academic education and professional training in the various disciplines of aviation:

- Air Traffic Management,
- Aviation Management,
- Pilot Training,
- Airframe and power plant maintenance,
- Aircraft electricity and electronics.

The faculty offers an intensive combination of theoretical and practical classes complying with ICAO standards in well-designed and equipped laboratories, workshops and state of the art simulators.

Besides the training facilities, the faculty operates its own international airport (LTBY-Hasan Polatkan Airport) serving for domestic and international flights and tower control facility providing air traffic services to the commercial and training flight operations.

ESTU has its own international airport and flight operations are performed by the personnel of airport together with the academics that are the permanent employees of ESTU. ESTU performs its own fleet management and aircraft maintenance operations compatible with ICAO and EASA. The aerodrome control service is performed by the DHMI by providing controllers only in the ESTU facilities.

Also, the academics of Air Traffic Management and Air Transportation Management Departments provide scientific (theoretical) support, which will be combined by practices at the airport.

4.1.1 Airport and Airspace

ESTU educational campus is unique in including an international airport where all educational and operational facilities create aviation culture with the support of engineering faculties in addition to the faculty of Aeronautics and Astronautics.

The real environment for FACT validation testing studies will be performed in the ESTU Hasan Polatkan International Airport and its airspace including campus area for the drone testing. The ICAO code of airport is LYBY and IATA code is AOE. The airport is used for the training and general aviation mainly and commercial flights from mostly for Brussels, Lion and Mecca pilgrim travel flights operated by Turkish Airlines, Pegasus, TUIFly, Tailwing and Corendon Airlines on charter bases. Campus and airport areas can be seen at aerial photo below.

Figure 8. LTBY-Hasan Polatkan Airport

ESTU airport has single runway which is 09-27 (3000x45 meters) with parallel taxiway which can be used as an emergency runway. Runway and taxiways are lighted for the night and low visibility operations. It has two aprons; one is located in front of the control tower and other is located in front of the RFF facilities. The runway 09 only has ILS CATI for the low visibility operations. Airfield has VOR/DME and NDB facilities operated by the ESTU ATSEP personnel. The operational details of airfield can be seen at the AIP chart of Hasan Polatkan Airport below.

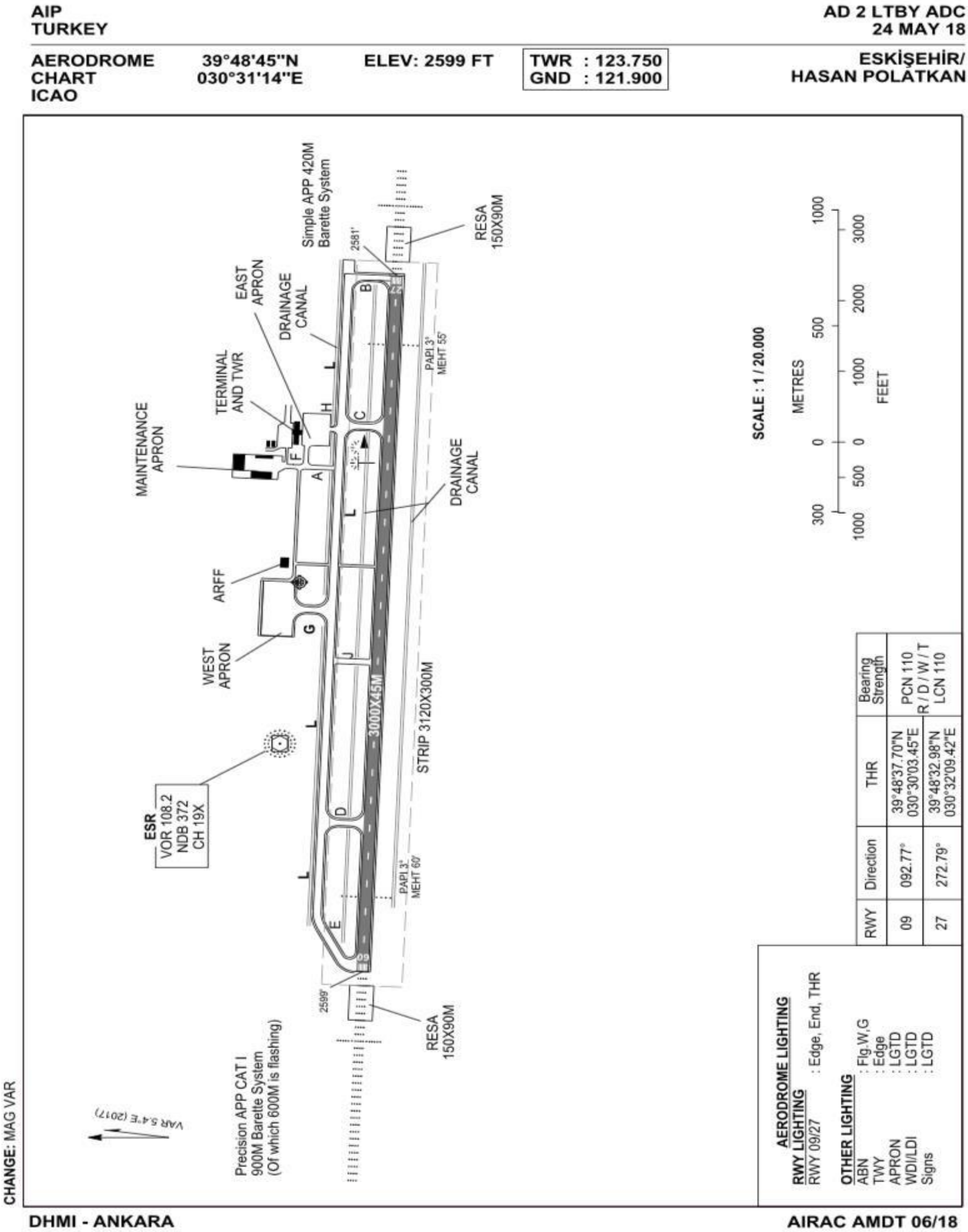


Figure 9. LTBY Chart

ESTU aerodrome control zone is limited by the south of the airfield due to military airbase approach and departure zones. LTBY and its Anadolu airspace is operable for the other ways with the vertically limited with 1000 ft. AMSL. The terminal manoeuvring areas is operated by the neighbour military airbase RAPCON air traffic controllers with a high level of communication and coordination. In other words, air traffic responsibility belongs to Military RAPCON above 1000 ft. AMSL around the LTBY. The aerodrome circuit is operated for the northern side of the field for runways 09/27. Flight training areas are mainly designated and used as the west side of the field which is 20 NM away from the aerodrome and its details can be seen below parted from Turkish AIP.

4.1.2 Aircraft Fleet

ESTU performs flight training operations from basic PPL through ATPL-Frozen licensing requirements at international standards. ESTU operates its own fleet consisting of 3 Cessna 172 Skyhawk for adaptation phase, 5 Socata TB-20 Trinidad for maturation phase and 2 KingAir C-90 GTI for the multi

Figure 10. Cessna 172 Skyhawk Aircraft for Adaptation Phase

Figure 11. Socata TB-20 Trinidad Aircraft for Maturation Phase

engine phase, images of which can be seen below. The fleet will play role during the FACT validation testing phases.

Figure 12. King Air C90 GTi Aircraft for Multiple Engine Phase

The aircraft fleet is operated by ESTU flight instructor pilots and flight training students depending on the training phases. ESTU has its own aircraft maintenance hangar and qualified aircraft maintenance technicians who perform planned and unplanned maintenance operations with university resources.

4.1.3 3D Aerodrome Control Simulator

The faculty extended its capabilities in Airport and ATM research by the installation of the new radar and 3D and 360 degrees' aerodrome simulator systems (6 different simulation environments including the busiest Turkish airports). The system provides creating very effective airport and air traffic scenarios as well as testing even emergency and dangerous situations in the air and on the ground.

ESTU aerodrome simulation general features can be listed as:

- Realistic aerodrome image with 360 and 3D view,
- Realistic aircraft and operational performances,
- All weather conditions,
- Emergency conditions,
- 6 different airport layouts including validation airport and airspace for the FACT,
- Airport layout design tool FAB,
- 4 operational positions and 1 supervisor with 2 pseudo pilot positions,
- Pseudo pilot positions can be extended with radar pilot positions,

Figure 13. 3D Aerodrome control simulator

The aerodrome simulation will play an important role to create and mature FACT validation scenarios during the project studies. With the support of advanced features of the simulator and experts' collaboration, FACT validation scenarios will be developed and tested virtually to manage project objectives better considering safety and efficiency issues. System is capable of operating unmanned aerial systems with general and commercial air traffics together.

4.2 Honeywell

Honeywell will provide experimental on-board avionics to support use cases and scenarios described in section 4. It will cover:

- Systems installed onboard GA aircraft: Experimental CNS device and situation awareness application installed on-board a tablet or mobile (pilot's choice).
- Systems installed on-board drones: Experimental CNS device
- Experimental implementation of selected U-space services (including emulation of CIS function) communicating with on-board experimental CNS devices and processing data received from them and from ground systems (ground control station of remote pilots and ATC).

4.2.1 CNS Experimental Device for GA Aircraft or Rotorcraft

The CNS experimental device for GA aircraft or rotorcraft will be designed as a stand-alone system without any direct connection to integrated aircraft avionics. It will be powered by its own battery. It will contain own GPS to provide position information and 5G cellular chip (provided or agreed with Nokia) for communication with ground infrastructure. In addition, the system will provide ADS-B In capability and optionally (to be agreed in the later stage) it can provide also low power ADS-B Out capability as developed and explored within SESAR2020 EMPHASIS project. Extensive logging function will ensure that all validation parameters are safely stored and available for post-processing analysis of the scenarios and CNS performance.

As the system will be independent of integrated avionics, its installation will consist of mechanical fixation of the device inside the vehicle and installation of antennas (GNSS, cellular, and ADS-B In).

4.2.2 GA Situation Awareness Application

GA Situation Awareness mobile application will be used to demonstrate benefits for GA pilots resulting from information available due to the enhanced CNS capabilities of mixed traffic and availability of supporting ground services. It will be installed on a tablet (preferred setup) or mobile phone and wireless connected with experimental CNS device. Beyond the terrain and traffic layouts it will be also able to show alerting information and messages from implemented ground services.

4.2.3 CNS Experimental Device for Drones

The CNS experimental device for drones will be connected with drone's flight guidance computer using Mavlink protocol over a serial link and powered by drone's batteries. Beyond processing card it will include ADS-B In function and 5G cellular chip (provided or agreed with Nokia) for communication with ground infrastructure. It will read telemetry (and trajectory) information from drone's flight guidance computer and report it to the ground services. Extensive logging function will ensure that all validation parameters are safely stored and available for post-processing analysis of the scenarios and CNS performance.

Installation of the system will consist of mechanical fixation of the device including cellular and ADS-B In antennas on the drone.

4.2.4 Experimental Implementation of Selected U-space Services

U-space services will be implemented as a set of cloud SW modules interfacing with cellular network and providing interfaces to drones' operators and for ATC. The purpose of the implementation is not to represent deployment-ready U-space services but to enable evaluation of feasibility of such services through explored CNS enablers, in particular cellular network. In this context, implementation of services has to mainly introduce realistic latency (associated with ground processing of received data) into overall end-to-end traffic surveillance applications and provide core functionality (primarily information sharing and alerting) to support demonstration of benefits to different stakeholders.

The core of the system will be a cloud storage maintaining actual snapshot of the traffic (position, trajectories (when available) and airspace information. This storage system will be complemented with the following main functions:

- Tracking function processing position reports received via cellular network
- TIS/FIS reports generation and transmission function
- Conformance monitoring function with alerting
- Dummy function emulating outputs of separation management for evaluation of clearance communication loop

- Communication functions supporting external interfaces with remote operators and ATC.

4.3 Nokia DAC architecture

Nokia will provide a private wireless network using 5G stand-alone (SA) connectivity in a 5G NR frequency band (depending on available frequency licenses). The core network will be based on Nokia's NDAC platform. The radio access network (RAN) will comprise a number (say 3-5) of micro or macro outdoor remote radio heads (RRH) connected to Nokia's 5G AirScale System Module.

Nokia DAC is a carrier/industrial grade digital automation service platform providing private 4G and 5G connectivity and a suite of applications for enterprises and verticals. It includes a reliable, secure, and high-performance private wireless network that is scalable according to needs. Nokia DAC offers an easy to use interface for network management tasks, such as managing SIM cards, adding and removing devices and features, viewing real-time information via Nokia DAC Manager (a web based user interface) on the status and utilization of network and devices as well as 5G radio network and Edge cloud health. In a commercial deployment, the Nokia DAC Manager can be used by the customer personnel directly.

Operating a private network requires very limited manual work as Nokia DAC service is orchestrated and maintained from Nokia DAC regional clouds, which are designed with high availability and secure architecture including multiple levels of redundancy, and a continuously increasing level of automation. Cloud-based management is enabled with the connection of the local Edge to the regional cloud through the Internet.

3GPP standardization

5G is standardized by 3GPP in releases. The very first 5G standards were specified in Release 15, which was fully completed in June 2019. Release 15 covers both the so called non-standalone (NSA) and standalone (SA) options. The main use case for NSA architecture is evolution from 4G networks using the existing 4G evolved packet core (EPC), 4G radio layer as the anchor band and 5G radio as the capacity layer based on 4G-5G dual connectivity architecture.

Release 15 also specified SA architecture, which supports pure 5G radio access together with the new 5G core network. The focus of Release 15 was on enhanced Mobile Broadband (eMBB) use cases. Release 16 introduces capabilities for industrial use cases such as Ultra Reliable Low Latency Communication (URLLC). Release 17 will focus on high numbers of IoT devices also known as massive Machine-Type Communication (mMTC). The completion date for Release 16 was in June 2020 and Release 17 is targeted for December 2021.

3GPP 5G SA architecture overview

5G radio access

5G SA includes the next generation radio access network (NG-RAN), which connects to the 5G Core (5GC). NG-RAN provides 5G NR (New Radio) connectivity for User Equipment (UE). The 5G NR base station is called gNB in 3GPP specifications.

The high-level NG-RAN architecture is depicted in Figure 3GPP NG-RAN overall architecture [3GPP TS 38.300]. The focus in this document is on gNBs having Xn interface between them for handovers and generic NG interfaces to 5GC functions. The NG interface can be further split into control plane N2 from gNB to AMF and user plane N3 from gNB to UPF as described in 5G Core.

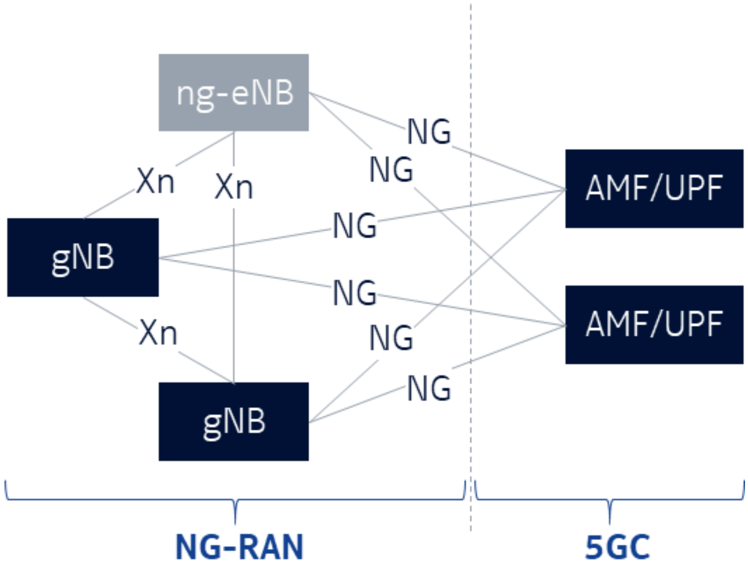


Figure 14. 3GPP NG-RAN overall architecture [38.300].

5G Core

The 5G core (5GC) network has changed from previous generations in a few important principle ways. Firstly, there is clear separation between user plane and control plane functions starting from the very first 5G architecture based on 3GPP Release 15. This enhancement has been also added later to the 4G evolved packet core (EPC). The second significant change is service based architecture for control plane functions. Network functions (NF) expose their services to other NFs to be consumed. 5G system architecture is depicted in Figure 3GPP 5G system architecture with service based interfaces [3GPP TS 23.501]. Service based interfaces (SBI) are shown in the figure as “Nxxx” - so N followed by the NF abbreviation in lower case letters (e.g. Nsmf for SMF). The SBIs are based on HTTP/2 protocol with JSON as application layer serialization protocol [3GPP TS 29.500].

The 5G network provides PDU connectivity service, which enables exchange of PDUs (Protocol Data Unit) between UE and Data Network (DN). A PDU session is an association between the UE and a Data Network that provides a PDU connectivity service.

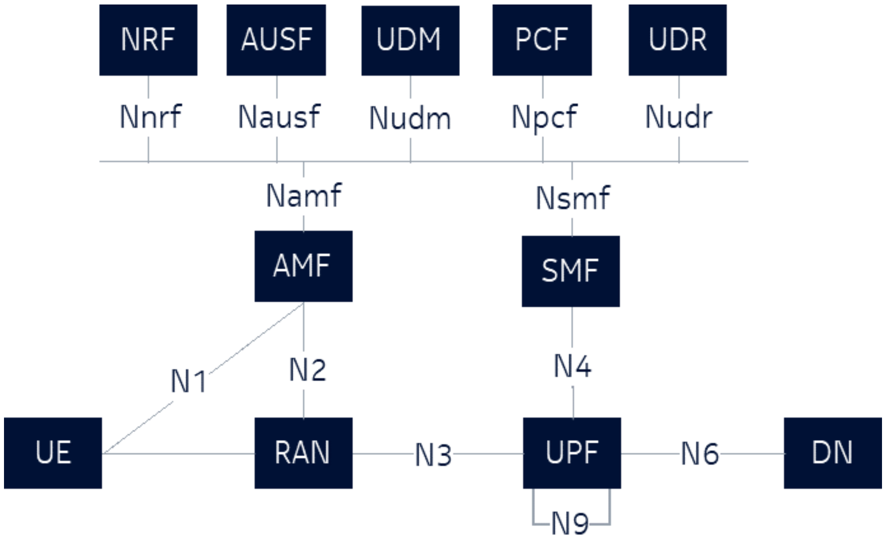


Figure 15. 3GPP 5G system architecture with service-based interfaces [3GPP TS 23.501]

All the specified 5GC NFs are not mandatory in every deployment. The most important functions are:

- AMF: Access and Mobility Management Function
- AUSF: Authentication Server Function
- SMF: Session Management Function
- UDM: Unified Data Management
- UPF: User Plane Function
- UDR: Unified Data Repository (not shown in the figure above)
- NRF: Network Repository Function

Their main roles are as follows:

- AMF terminates NAS signaling from UE (N1 interface) and handles network registration, connection management and mobility management related procedures including authentication supported by AUSF. AMF also interacts with SMF, which terminates the session management part of NAS signaling.
- AUSF provides UE authentication service.
- SMF handles PDU session management and UE IP address management procedures, for example.
- UDM is needed for subscription management and generation for 3GPP AKA authentication credentials.
- UPF takes care of user plane packet routing and forwarding, acts as a mobility anchor point, provides interconnection to the external Data Network (DN) and handles user plane QoS.
- UDR is storage for subscription data used by UDM.
- NRF supports registration and discovery of network functions in the service-based architecture.

4.3.1 Nokia DAC 5G SA solution architecture

A complete 3GPP 5G SA system is deployed on the customer premises with 5G gNBs and all 5GC NFs on the edge server, also called the Edge. Thus, the gNBs together with the Edge comprise a fully operational 5G SA network. The Edge is connected to a regional cloud (i.e. Nokia DAC data center, DC), which provides secure cloud-based management functions. 5G SA networks in customer premises are managed via the regional cloud, which provides management tools for operations personnel as well as secure access to a web-based customer portal.

The gNBs connect via the customer IP network to AMF and UPF functions in the Edge. The gNBs also have O&M connection to RAN management service in the Edge.

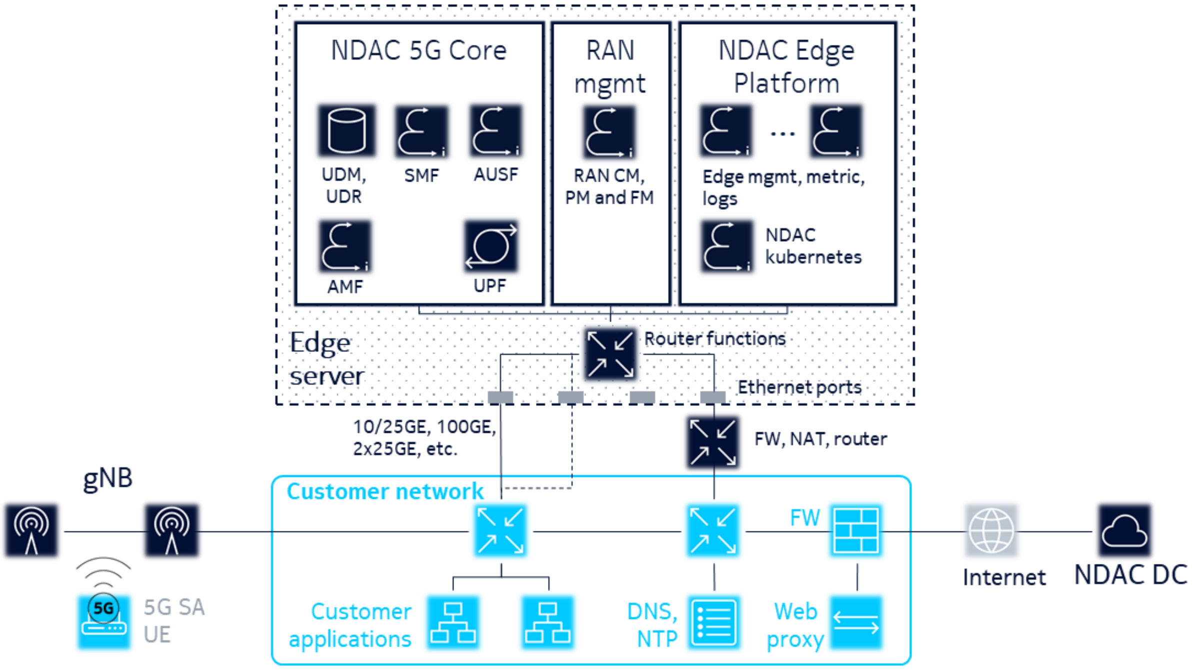


Figure 16. 5G core NFs and support functions in the Edge

4.3.2 5G SA solution components

This section provides a general overview of the Nokia DAC 5G SA components with selected examples.

Classical 5G gNB architecture

Nokia DAC supports classical gNB architecture comprising Nokia AirScale products both for indoor and outdoor use cases. Nokia's classical 5G gNB consists of AirScale System Module (SM) and various Remote Radio Head (RRH) options for different frequency bands and use cases.

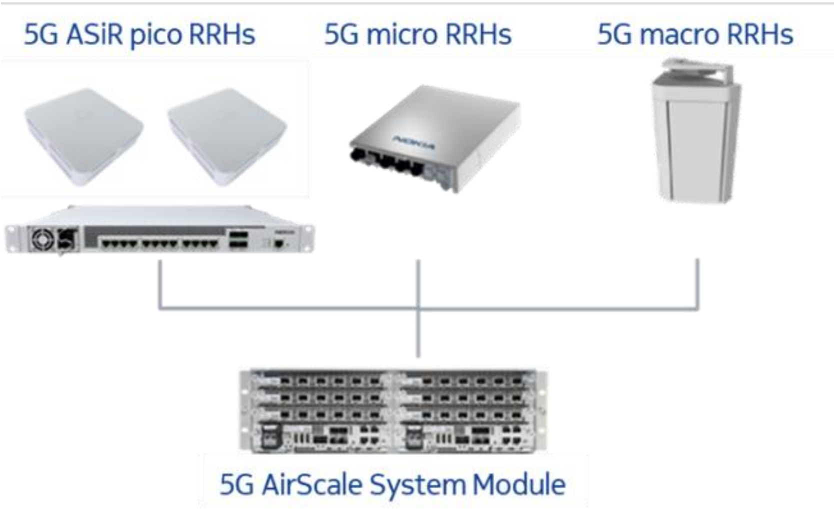


Figure 17. Overview of Nokia AirScale based 5G NR options in Nokia DAC

- AirScale system module

AirScale includes at least one common plug-in unit and one or more capacity plug-in units in a subrack. Figure illustrates an example of a 5G baseband configuration in an indoor subrack.

The common plug-in unit provides backhaul Ethernet ports, base station synchronization, central control functions and base station operation and maintenance functions. The capacity plug-in units perform cell specific baseband processing and include optical CPRI or eCPRI interfaces to radio units i.e. RRHs. CPRI (Common Public Radio Interface) and eCPRI (enhanced CPRI) are standardized interfaces between baseband processing and the radio unit for all radio technologies (2G, 3G, 4G and 5G).

Figure 18. AirScale subrack example with one ASIK and two ABILs

- AirScale radio units

Nokia AirScale radio units connect to digital interfaces (CPRI or eCPRI) of AirScale SM. The radio unit includes a transmitter, which converts the digital signal to RF and amplifies it. The RF signal is radiated by connected antenna. The receiver function of the radio unit converts the received RF signal to a digital signal. There are different radio units or RRH products for specific frequency bands or frequency ranges and desired maximum output power levels as well as for different MIMO configurations.

The 5G SA solution is available initially for Sub 6 GHz radios (FR1) and the primary bands supported bands are, for example, n41 (2496 – 2690 MHz), n77 (3300 – 4200 MHz) and n78 (3300 – 3800 MHz).

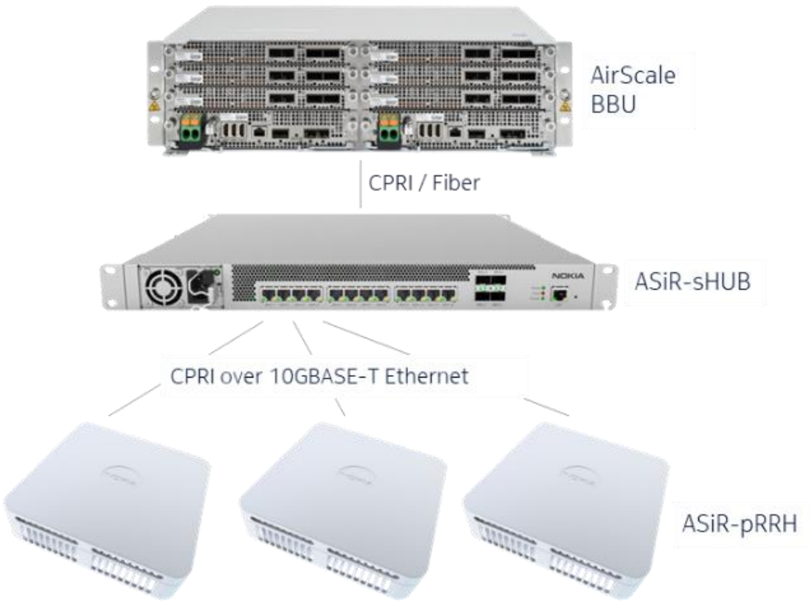


Figure 19. 5G SA solution equipment

Nokia DAC Edge

- HW options

5G enables over 1 Gbps downlink speed and about 100 Mbps in uplink for a single UE with 100 MHz spectrum. Practical downlink peak throughput may be some 100's of Mbps per UE, but the total network data rate can be several Gbps, when there is a large number of simultaneously active high bit rate connections such as with 4K video streams.

Therefore, Edge HW must have minimum 10 GE interfaces and adequate CPU resources for at least 1-10 Gbps throughput.

4.3.3 Edge site

Transport network dimensioning for an Edge site can be planned based on expected peak traffic for the whole network. In practice, the 5G system is expected to require over 1 Gbps data rates and therefore 10 GE link is the typical minimum transport connection between the Edge and customer network.

- Customer transport example

Nokia DAC Edge and gNBs are connected to the enterprise IP network. Each gNB requires in typical configuration one IP address, which is routable in the enterprise network. AirScale SM can be connected with a 1 GE or 10 GE link to the customer access switch/router depending on the required maximum gNB data rate. AirScale SM supports also resilient backhaul transport with 2 Ethernet links.

Connecting the Edge with minimum 10 GE link to customer switch/router is recommended. See section Edge site for higher capacity configuration options. The enterprise must allocate an adequate number of IP addresses for the 5G system. A pool of addresses are needed for backhaul interfaces (N2, N3 and O&M) in the Edge as well as for 5GC internal interfaces between network functions in the geo-redundant Edge (see Edge Redundancy). Furthermore, addresses are needed for the 5G devices (UE pool per DNN), which use the 5G network to access the enterprise IP network (or Data Network, DN).

The Edge connects with VLANs to the customer network. One VLAN is used for gNB backhaul connections. Further VLANs connect UEs with different DNN subscription to different Data Networks. The transit network is configured for each VLAN. Figure Overview of Nokia DAC integration with the enterprise IP network depicts a simple example with one VLAN for 5G RAN backhaul and two VLANs for two different DNNs.

Nokia DAC 5G SIM cards

The Nokia DAC solution includes SIM cards. The same Nokia DAC SIM cards can be used with 4G, 5G NSA and 5G SA systems. All UEs in the trial network shall be equipped with the Nokia SIM cards.

Nokia DAC management

- Nokia DAC Manager

Nokia DAC customers receive access to Nokia DAC Manager, which allows them to perform basic management actions.

Nokia DAC Manager is used for basic monitoring and operations of the customer network. It provides a quick view to the overall network status and offers the possibility to perform simple network management actions.

The following information can be viewed via Nokia DAC Manager:

- Location of all the private networks
- Status of 5G gNB & Edge hardware
- Network statistics (live and historical data transfer)
- Network settings (DNNs, IP configurations)
- Status of SIMs and subscription data (QoS, DNN, static IP, Framed routing)
- Connected devices

With Nokia DAC Manager, customers can perform the following operations:

- Create a private network
- Activate/de-activate, reset and shutdown a network
- Manage IP configurations (transit VLANs and IP networks, DNN mapping to network interface,
UE IP pool per DNN, Framed routing)

- Provision/deprovision SIMs, QoS modification of SIMs, set static IP per SIM
- 5G gNB management – Enable, disable, reboot
- User/Account management

4.4 ITU

Unmanned air traffic around ESTU aerodrome will be realized by two drones which are owned by Aerospace Research Center (ARC) of Istanbul Technical University (ITU). These drones are middle size quadcopters with app. 10 kg take-off weight, and powered by two 6-cell 22 Ah LiPo batteries which provides approximately 30 minutes flight time. The drone picture is given below.

Figure 20. ITU drone image

The ground control software is developed by ITU ARC and will be edited according to the system architecture and validation requirements of the FACT project. The main screen of the ground control software is shown below. A built-in 3D geospatial visualization engine is supported with a 2D map. User interface design will assist the operator while conducting the validation tests. A VoIP interface is planned to be integrated in the user interface.

Figure 21. VoIP interface

Both drones will be connected to the ground station using high-power industrial scientific medical (ISM) band C2 radios with time-division multiplexed (TDM) star network topology. Their tested range is 5 km. C2 link ensures the drone status vector (position, velocity, attitude etc.) at 1 Hz.

The flight control software of the drones is capable of tracking polynomial trajectories defining position, velocity and acceleration references. The ground control software will be capable of pre-flight trajectory planning, according to the waypoints and geofence/geocage constraints provided by the operator. The anticipated maximum trajectory tracking error is 5 meters. The geocage may consist of an altitude limit, a circle centered on the drone's home location, or a polygon defined by the operator. When the drone hits the geocage it can perform one of the three reactions, return to home, land, or hold position, according to its safety configuration.

4.5 SARP AIR

The FACT objectives will support aviation safety and efficiency by better monitoring and management of the air traffic including unmanned systems in different categories and cost-efficient integrated solutions.

Initially FACT methodology and technological solutions will be tested in ESTU aerodrome control simulation environment and transferred to the real air traffic environment of Hasan Polatkan International Airport (LTBY). The airport and the campus together are suitable opportunity to realize and test FACT objectives to serve focusing on general aviation and unmanned aerial traffic integration with the other air traffic entities.

Sarp Air (formerly Sarp Havacılık Lojistik Turizm ve Sanayi Tic A.S) has two aircrafts under operation; helicopter Sikorsky S76 B and airplane Challenger 604 but will provide only helicopter for the project in accordance with the use cases of this project. Since 2004, the company has been providing airtaxi services and maintenance services as well.

Figure 22. SARP AIR aircraft

Sarp Air operates its own national heliport serving for helicopter flights and tower control abilities providing air traffic services to the helicopters only needs services from Sarp Heliport.

Sarp Air performs its own fleet management and aircraft maintenance management and execution operations compatible with SHY/ ICAO and EASA.

Figure 23. SARP AIR heliport and hangar

5 Validation Risk Management Plan

5.1 FACT Risk Management methodology

The risk management process involves the systematic application of policies, procedures and practices to the activities of communicating and consulting, establishing the context and assessing, treating, monitoring, reviewing, recording and reporting risk. This process is illustrated in Figure x1.

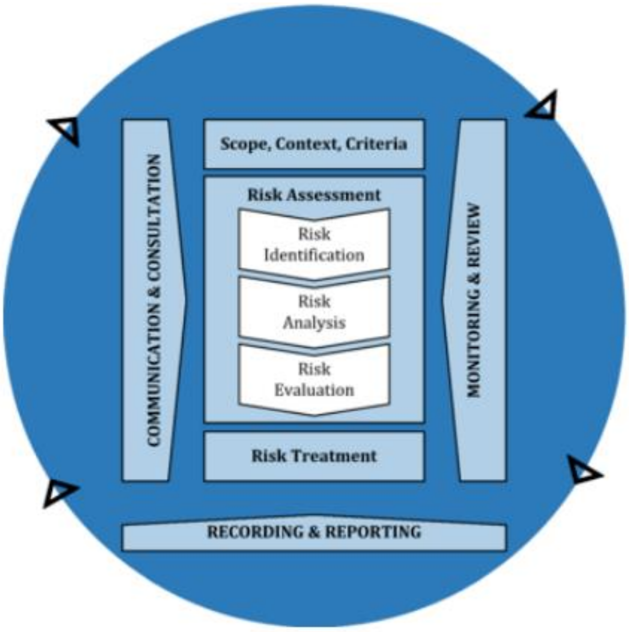


Figure 24. Risk management process Ref: https://www.iso.org

The risk management process should be an integral part of FACT project validation management and decision-making and integrated into the structure, operations and processes of the validation.

5.2 Risk identification

The FACT identifies risk by assessing GA aircraft and drone moving data, operator feedback, safety incident and accident data and stakeholder feedback. Stakeholders' feedback can come in many forms such as focus group studies or scenario development and execution studies.

FACT consortium focused at this stage on the initial risk identification among the partners about the potential validation scenario execution activities. Table 2 below represents the preliminary risk identification inputs and their mitigation strategies.

Table 2. Potential risk and hazards estimated by the project partners.

	Potential Risks/Hazards		Risk/Hazard Mitigation Plan	
Partner	**1st Validation**	**2nd Validation**	**1st Validation**	**2nd Validation**
Eurocontrol	1) Inoperative geo caging	1) Radio loss of GA aircraft 2) Loss of communication between validation actors	1) Put observers on the ground in radio contact with UAS remote pilot.	1) Abort validation test 2) Abort validation test
HONEYWELL	1) Due to COVID situation, limited possibility to test different networks with partners. 2) Situation on the market (availability, delivery delays) with cellular chips	1) Availability of suitable cellular chips for frequency used in Nokia's experimental network. 2) Integration of the experimental CNS devices on the vehicles (drones and GA).	1) Cooperation with Czech universities and telecommunication operators. 2) Several chips already ordered/delivered for 1st validation but may not be reusable for final demo (frequency to be confirmed).	1) Coordination with Nokia to ensure the availability of suitable chips and their smooth integration into experimental CNS device. 2) Integration coordination starting sufficiently in advance to prevent issues during the preparation of operational demo.
NOKIA	1) Spectrum not available/ lead to shift in the order and deployment	1) Spectrum not available/ lead to shift in the order and deployment	2) Early start of applying for the test licence	1) Early start of applying for the test licence
ESTU	1) Collaboration difficulty between partners due to Covid-19 measures.	1) Collaboration difficulty between partners due to Covid-19 measures. 2) Operational safety and efficiency related issues. 3) Equipment transportation and set up issues from abroad.	1) ESTU started F2F collaboration with the national partners.	1) ESTU started F2F collaboration with the national partners. 2) ESTU collaborates with partners and national parties to comply with the safety management procedures in

				airport and national levels. 3) Communication started with the project partners and national authorities such as Turkish Information and Communication Organization.
SARP AIR		1) Drone battery 2) Mechanic disorder 3) Communication failure 4) 5G effects 5) Lateral and vertical separation 6) CNS weight		1) Well planned flight time 2) Emergency application 3) Action to be taken should be defined prior to flights 4) Unknown 5) 500 feet vertical, 2 Nm lateral 6) Effects W&B on drone, no effect for the GA
ITU	1) Loss of C2 link 2) Hardware or software failure of the drone components 3) Unsuitable autonomous landing site	1) Malfunction of VoIP services 2) Malfunction of USSP provided services	1) Autonomous return to home action will be defined as failsafety for loss of communication 2) RC control will ve active and pilot will have manual motor shutdown switch 3) Remote pilot will have the highest authority to change the landing site	1) Pilot will be accessible via personal mobile phone 2) Periodic heartbeat messages or acknowledge messages to request messages will be sent by the USSP that informs about its system health
AOPA	1) Scenarios defined incomplete or unrealistic.	1) Data recorded from scenarios not detailed enough, misleading or incomplete.	1) Discuss scenarios with relevant user groups.	1) Analyse results from Validation 1, refine scenarios and update/ correct data collection

				methods and quality.

5.3 Risk assessment

Risk assessment is the overall process of risk identification, risk analysis and risk evaluation. Risk assessment should be conducted systematically, iteratively and collaboratively, drawing on the knowledge and views of stakeholders. It should use the best available information, supplemented by further enquiry as necessary.

The FACT undertakes quantitative and qualitative analysis and evaluates risk by using recommendations from the combination of sources and methodologies:

- ISO31000: Risk Management,
- ICAO's Safety Management Manual Doc 9859,
- Common Risk Management Framework (CRMF) (CASA, 2017),
- Due diligence utilizing a precautionary approach.

In addition, in accordance with the national and international safety rules, FACT seeks to ensure appropriate airspace and aerodrome operational arrangements for the validation activities.

5.3.1 Risk Matrix

FACT inspires from the ICAO DOC 9859 for risk assessment matrix of likelihood and severity of risk assessment. "*Safety risk probability is the likelihood that a safety consequence or outcome will occur*" (ICAO Doc 9859, 2018). During the FACT scenario validation potential consequences will be considered.

Once the probability assessment has been completed, the next step is to assess the severity, considering the potential consequences related to hazard. "*Safety risk severity is defined as the extent of harm that might reasonably be expected to occur as a consequence or outcome of the identified hazard*" (ICAO Doc 9859, 2018). Safety risk matrix is given in the Table 3 below.

As provided in Table 3, safety risks are classified using a safety risk probability and severity using 5-scale for both severity and probability.

Table 3. Safety risk matrix (Doc 9859, 2018).

Safety Risk	Severity				
Probability	Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent – 5	5A	5B	5C	5D	5E
Occasional – 4	4A	4B	4C	4D	4E

Remote – 3	3A	3B	3C	3D	3E
Improbable - 2	2A	2B	2C	2D	2E
Extremely Improbable - 1	1A	1B	1C	1D	1E

In the FACT validation activities safety risks are assessed conceptually as acceptable, tolerable or intolerable as advised in Doc 9859. The safety risk tolerability is given in Table 4 below.

Safety methodology is further explained in sections 5.3.2, 5.3.3 and 5.3.4 .

Table 4. Safety risk tolerability (Doc 9859, 2018).

Safety Index Range	Safety Risk Description	Recommended Action
5A, 5B, 5C 4A, 4B, 3A	INTOLERABLE	Take immediate action to mitigate or stop the activity. Perform priority safety risk mitigation to ensure additional or enhanced preventative controls are in place to bring down the safety risk index to tolerable.
5D, 5E, 4C, 4D, 4E, 3B, 3C, 3D, 2A, 2B, 2C, 1A	TOLERABLE	Can be tolerated based on the safety risk mitigation. It may require management decision to accept the risk.
3E, 2D, 2E, 1B, 1C, 1D, 1E	ACCEPTABLE	Acceptable as is. No further safety risk mitigation required.

5.3.2 Simulation and testing

FACT makes use of ESTU 3D aerodrome control simulation facilities. This simulation environment is planned to be used for scenario analysis studies and to assess alternative options. Simulation and testing are used as planning tools or to conduct analysis and feasibility studies of airspace risk and should be considered purely indicative in their input.

5.3.3 Bow-Tie Analysis

Qualitative and visual BowTie method will be used during validation phases for FACT safe operations in virtual and real environment while performing the scenario executions. BowTie is a useful tool to perform risk assessments and communicate all relevant aspects of risk. BowTie model supports the five general phases of the safety management systems which are: (1) Describe the system, (2) Identify the hazards, (3) Analyze risk, (4) Assess risk and (5) Treat (mitigate) the risk.

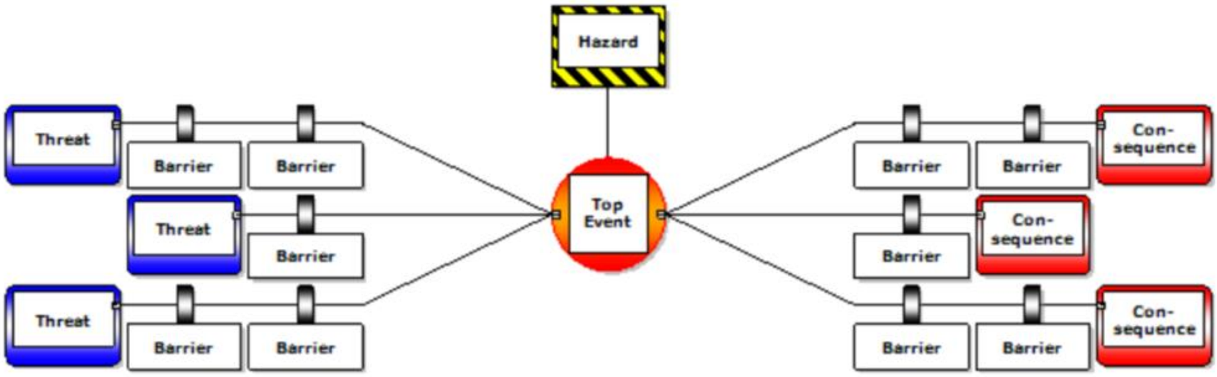


Figure 25. BowTie visual sample (BowTie Flyer)

5.3.4 Expert Panel

The FACT accesses expert panel input on a regular basis through both internal and external means such as related operators in ESTU and project Advisory Board members. Expert panel input can be derived on a case-by-case basis through generative interviews and by invitation to stakeholders and operators. During all validation activities, the FACT may also facilitate Hazard Identification (HAZID) Workshops to address specific issues.

5.4 Risk Mitigation/Treatment

The purpose of risk treatment is to select and implement options for addressing risk. Risk treatment involves an iterative process of: formulating and selecting risk treatment options; planning and implementing risk treatment; assessing the effectiveness of that treatment; deciding whether the remaining risk is acceptable; if not acceptable, taking further treatment. As the project progresses according to the timeline, risk assessment and mitigation activities are already in place and necessary actions have been taken since the beginning of the FACT.

5.5 Safety Assessment Plan

As described in the previous sections, at this stage the risk identification and their initial expert judgements were performed, and methodology agreed. As the next steps, the identified risks will be further evaluated within the first validation activities, namely operational simulations at ESTU simulator with subject matter experts. Results of these simulations will allow to refine initial risks assessment and define appropriate mitigation means for the operational demo. These results will be documented in the first validation report (D5.2), and the agreed mitigations will be implemented/deployed for the final operational demo (second validation activity).

6 References

[1] CASA (2017), Airspace Risk and Safety Management Manual, D16/374307.

[2] FAA (2009), Risk Management Handbook, FAA-H-8083-2.

[3] ICAO (2018), DOC 9859 Safety Management Manual.

[4] International Telecommunication Union (2008). Series E: Overall Network Operation, Telephone Service, Service Operation And Human Factors: ITU T-REC-E.800

[5] International Telecommunication Union (2001). Series G: Transmission Systems and Media, Digital Systems and Networks Quality of service and performance: ITU-T-REC-G.1000

[6] ISO 31000 Risk Management https://www.iso.org/publication/PUB100426.html (21.09.2021)

Annex A Quality of Service

The different QoS definitions from ITU-T-REC.E.800 are:

- ***Quality of service (QoS):*** Totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service.

- ***QoS requirements of user/customer (QoSR):*** A statement of QoS requirements by a customer/user or segment/s of customer/user population with unique performance requirements or needs.

NOTE – The customer/user needs may be expressed in descriptive terms (criteria) listed in the order of priority, with preferred performance value for each criterion. The service provider then translates these into parameters and metrics pertinent to the service (see [ITU-T E.802]).

- Q***oS offered/planned by service provider (QoSO):*** A statement of the level of quality planned and therefore offered to the customer by the service provider.

NOTE – Level of QoS the service provider plans to achieve (and therefore offers) to the customer/user is expressed by target values (or range) for measures of parameters pertinent to a specified service.

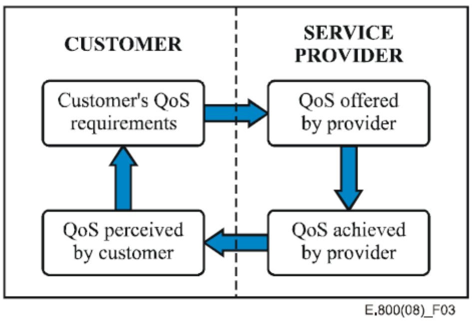
- ***QoS delivered/achieved by service provider (QoSD):*** A statement of the level of QoS achieved or delivered to the customer.

NOTE – Achieved or delivered QoS is expressed by metrics for the pertinent parameters for a service.

- ***QoS experienced/perceived by customer/user (QoSE):*** A statement expressing the level of quality that customers/users believe they have experienced.

NOTE – QoSE has two main man components: quantitative and qualitative. The quantitative component can be influenced by the complete end-to-end system effects (network infrastructure).

These QoS are all related as depicted in the following figure:



Section 5.3 of ITU-T-REC-G.1000 proposes generic QoS criteria. These criteria are adapted to match the FACT project objectives.