Development of an Unmanned Aerospace Test Site
U-space Sandbox

Project CACTUS

U-space Sandbox Concept

July 17, 2023

Prepared by: ANRA Technologies

Table of Contents

1. Introduction

ANRA Technologies, Inc. (ANRA), in partnership with the Tartu Science Park Foundation (TSP) are pleased to submit this document in support of the Development of an Unmanned Aerospace Test Site (U-space Sandbox). The project is called CACTUS, an acronym for "Competent Authority Coordinating Testing in U-space Sandbox."

This document satisfies Deliverable 2.1 (U-space Sandbox Concept).

2. Background

A sandbox is a test environment that enables the testing of technologies in environments close to real life conditions. The Estonia U-space sandbox would enable development and testing of U-space services before deploying the services in U-space airspace. In addition, testing may be conducted by organisations to identify if the services are compliant and meet the performance requirements, for testing new services and functionalities, and for testing by supplementary data service providers (SDSP) to ensure that any and all requirements are fulfilled. This document describes a concept for the U-space sandbox in Tartu, provides information on some sandboxes that are currently in deployment, discusses how a financial feasibility study can be conducted, and provides information on regulatory aspects.

3. U-space Roles and Responsibilities

This section lists the identified stakeholders that will support development of the sandbox:

- **Ministry of Economic Affairs and Communications (MoEC):** Member State
- **Estonia Transport Administration (TA)**: Project Sponsor and Competent Authority
- **ANRA Technologies (ANRA)**: Project Manager, U-space Expert, Technical Lead
- **Tartu Science Park (TSP)**: Estonian operations, stakeholder engagement, assessments
- **Estonian Air Navigation Service Provider (EANS):** Estonia Air Navigation Service Provider (ANSP)
- **Estonia Aviation Academy (EAVA):** Flight ops support
- **Tartu Authority (Tartu):** Local Authority

For resource allocation with respect to U-space:

- The **Member State** is responsible for implementing the U-space airspace.
- The **competent authority** certifies U-space service providers (USSPs) and common information service providers (CISPs) and performs an oversight function on U-space.
- **USSPs** provide mandatory U-space services, namely network identification service, geo-awareness service, traffic information service, and flight authorisation service, as well as

optional U-space services, namely weather information service and conformance monitoring service, depending on the nature of the U-space airspace. They must meet the established performance requirements and comply with the management system and business requirements stated in the Regulation (EU) 2021/664.

- **CISPs** disseminate necessary information between various stakeholders to ensure safe and proper functioning of the U-space airspace. The competent authority, ANSP, military authority, USSPs, and other relevant authorities provide and retrieve information from the CISP.
- **ANSPs** are responsible for performing dynamic airspace reconfiguration. This term is defined in GM1 Article 2(6) in AMC and GM to Regulation (EU) 2021/664 - Issue 1 as "short-term changes in manned traffic demand", which refers to manned traffic needing access to a U-space airspace for emergencies, military and state operations, and accommodating an increase in traffic demand due to an unexpected situation.
- **Manned traffic** is expected to be e-conspicuous, so that this information can be provided through the traffic information service by USSPs.
- **UAS operators** use the services that are offered by USSPs by establishing a Service Level Agreement (SLA) with them.

4. Concept Definition

4.1 Definition and purpose of a sandbox

A sandbox is a secure test environment where, even if something goes wrong, it won't directly harm host machines, operating systems, applications or data. The test environment functions as a metaphorical sandbox where you can play around with the system to see how it works.

A sandbox environment is enclosed and separate from your production environment in order to ensure that failures don't affect other fully working applications and data. However, a sandbox environment is similar to a production environment. The major difference is that the changes you make in a sandbox do not affect the production or live environment.

Products and services can be developed and validated in the sandbox before deploying it for commercial use. A sandbox can be used for regulatory and economic purposes, so that a suitable regulatory environment can be framed in order to accommodate and support the deployment of the innovative technology. Using the sandbox to initially use the technology also allows stakeholders to understand the risks associated with the technology and determine how these risks can be mitigated.

4.2 U-space sandbox in Tartu

The U-space sandbox in Tartu paves the way for the implementation of U-space in Estonia. It supports the development and deployment of unmanned aviation technologies, and positions Estonia as a forerunner of innovation. The U-space sandbox would be a research and development environment, which allows users to develop and validate U-space services and identify how different articles in Regulation (EU) 2021/664 can be implemented. It also identifies the performance requirements that must be established for U-space and would provide the opportunity to validate these requirements before commercialisation. Information on the use cases that can be performed in the U-space sandbox are described in Deliverable 2.3.

The U-space sandbox in Tartu is developed in two parts within project CACTUS, where the first part focuses on the development of the concept and roadmap of the U-space sandbox. As part of this, the concept is developed and validated through a Stakeholder Workshop, the means for conducting a financial feasibility study is provided, an action plan is developed, and the suitable use cases that can be conducted in the sandbox are identified. In the second part, the principles for ensuring technical and operational capacity of the competent authority are developed and validated through environment and software implementation, simulation and live testing, determining U-space sandbox services and technical performance, as well as a capability test for the competent authority.

4.3 Sandboxes in deployment

Market research was conducted for existing (or deploying) sandboxes to better understand best practices and lessons learned for developing and implementing the Estonian sandbox. There are several sandboxes pertaining to the UAS domain in the European Union (EU) and non-EU regions. Some sandboxes are established as regulatory sandboxes, while others aim to validate specific concepts of operations (ConOps) in specific environments. A few sandboxes and their purpose are described below:

- **Duisburg Regulatory Sandbox**

  Drone startup, doks. innovation GmbH, and steel producer, hyssenkrupp Steel Europe AG, won a Regulatory Sandboxes Innovation Prize that was established by the Federal Ministry for Economic Affairs. Therefore, a regulatory sandbox was established to transport laboratory samples using an automated drone in a safe, secure and efficient manner from the production site to the laboratory at thyssenkrupp Steel. The drone overflies public main roads and railway lines in order to reach the destination. Therefore, based on the results of the risk assessment, an operating permit, special exemptions, as well as a NOTAM had to be obtained.

- **Medifly Hamburg**

  Medifly Hamburg is a project that consists of several government and private partners, and it is funded by the Federal Ministry of Transport and Digital Infrastructure. It aims to transport urgently required medical goods between several hospitals and laboratories in urban areas, namely in north to south direction from Langenhorn to Harburg, and from west to east from Rissen to Barmbek-Süd. As the map below shows, the Medifly drone flew in Hamburg city, which being a densely populated area, therefore the operational authorisation that was obtained was subject to stringent conditions. Six flights were conducted in the areas marked below, including in the ATC zone of Hamburg's international airport.

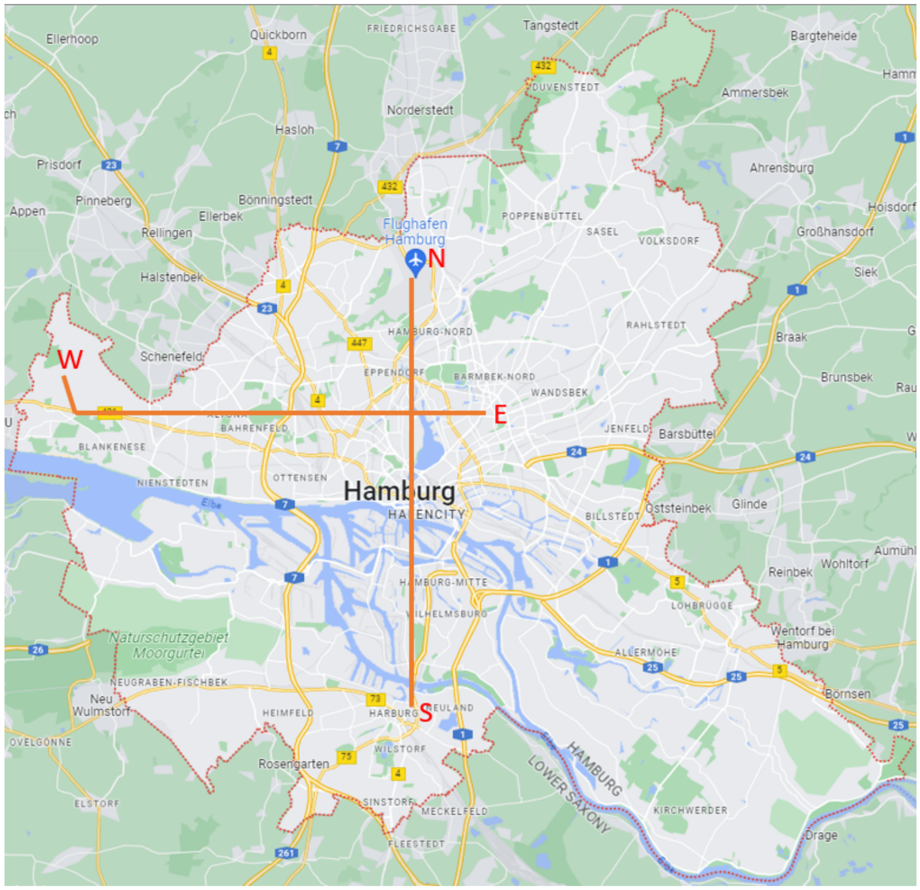

Fig.1: Flight path of Medifly drone in Hamburg

- **Mail Challenge**

  This sandbox was established to conduct drone-based postal service by Boeing Global Services in Neu-Isenburg. The fully automated postal service was conducted as a BVLOS operation between two sites, one in close proximity to Frankfurt Airport and another located in an urban area. Regulatory exemptions were provided by the Hesse Aviation Authority in order to permit fully automated drone flights, and in addition, approvals were required from the German ATC and the tower of Frankfurt Airport.

- **K-City Network**

  K-City is a virtual sandbox, which was established by the Ministry of Land, Infrastructure and Transport, Korea in 2018. It is a ‘virtual city’ for the industry and universities to test self-driving technology, collision avoidance systems, and other breakthrough technologies in a simulated environment. The virtual sandbox has a total surface area of 320,000 square metres and it is the world’s first test site for autonomous vehicles based on 5G networks.

Fig.2: K-City Network - 2022 Poster

- **Counter Uncrewed Aerial Systems Sandbox**

  This sandbox is located in Canada and is sponsored by the Department of National Defence. It follows the regulatory challenge concept, therefore calls for applications are launched at a specific period during the year, after which an innovator selection process is conducted. The topic of the regulatory challenge varies on a yearly basis, but this sandbox demonstrates concepts pertaining to counter UAS (CUAS). The sandbox has several goals such as allowing the defence and security partners to learn about capabilities and limitations of CUAS technologies, fostering development of technologies that are at a medium Technology Readiness Level (TRL), and encouraging interactions and partnerships among the CUAS community. The sandbox is open for a limited period of time during which the testing of the technology takes place, followed by interactions with specialists, regulators, and other stakeholders.

- **FAA UAS Test Sites**

  The main objective of the UAS Test Site Program is to provide verification of the safety of public and civil UAS, operations, and related navigation procedures before their integration into the national airspace system. The UAS Test Sites focus their research and demonstration on advancing technologies and concepts relating to Detect and Avoid, Command and Control, Airworthiness, BVLOS operations, standards for the safe operation of UAS in various airspace classes, air traffic control operational and communications procedures, multiple UAS operations, counter UAS, UTM, test and evaluation of proposed UAS standards, processes, and procedures, environmental impacts, and UAM. The following image shows the seven FAA UAS Test Sites:

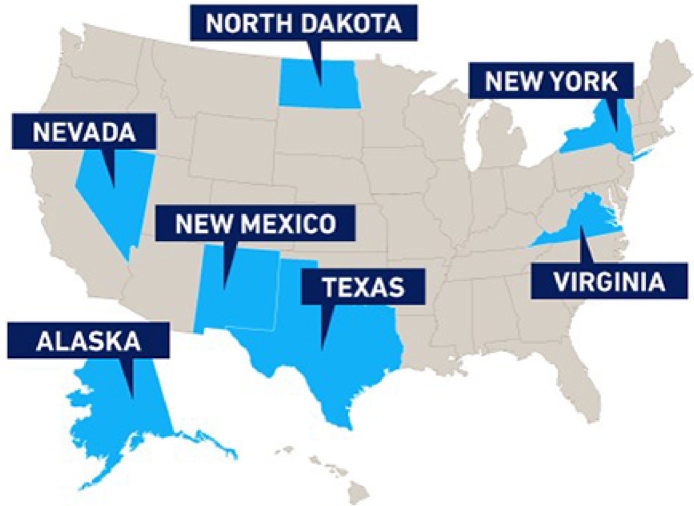

Fig.3: FAA UAS Test Sites

- **Financial Conduct Authority (FCA)'s Regulatory Sandbox**

  The Regulatory Sandbox provides innovative FinTech companies with the ability to test their products and services in a controlled environment and to identify if their business model would be attractive to customers. These companies obtain guidance from regulators on regulatory topics, including but not limited to, how a requirement could be interpreted in the context of their testing, and waivers or modifications if appropriate. An eligibility criteria has been established and companies are able to submit their application throughout the year if they meet the requirements. In case a company is not ready for testing, they can apply for a service called 'Innovation Pathways', which supports them in understanding the regulatory framework or for the 'Digital Sandbox', which is an online platform to support early-stage development propositions. Although this sandbox is not related to the aviation or drone industry, it has provided value to FinTech companies and boosted the economy through the business model that was adopted and the services delivered.

4.4 Methodology pertaining to the establishment of the sandbox in Tartu

Several criteria were established to identify locations where the sandboxes could be established.

- The test area had to be in a controlled and uncontrolled airspace, although that proved to be impossible as Tartu airspace was recently assigned as an uncontrolled airspace (Class G).
- The test areas were expected to be located in different parts of Tartu and to be connected to each other via corridors that can be activated or deactivated depending on the demand and the traffic situation.

- The test areas should cover sparsely populated areas, and in the future, it should be possible to expand it to populated areas.

Based on the above criteria, three areas were proposed for the short-term and mid-term:

- **Area around Estonian Aviation Academy (EAVA):** EAVA is located at the following coordinates, 58.3108664188422, 26.69349944076791, near Tartu Airport. Operations under 30 metres (100 feet) may take place at this location.

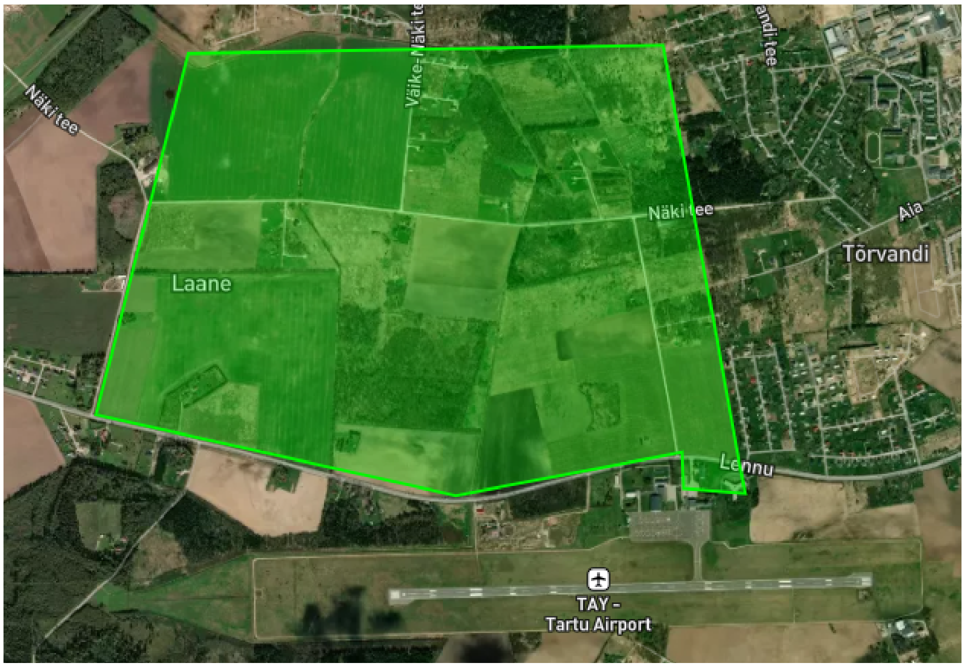

Fig.4: EAVA premises in Tartu

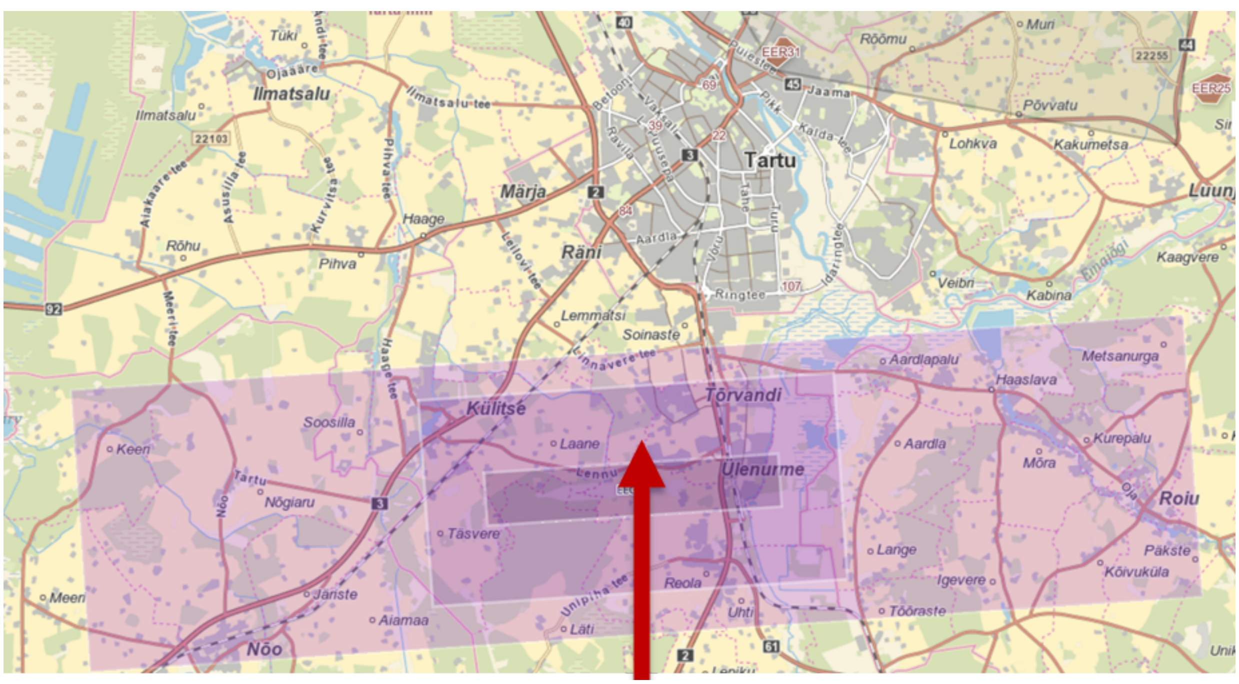

Fig.5: EAVA on Estonian Drone Map

- **Tartu Science Park (TSP):** It is located at 58.35664206562035, 26.676929973497266. A corridor can be established between EAVA and TSP, so that complex BVLOS operations using U-space services can be tested in the sandbox.

Fig.6: Corridor between EAVA and TSP

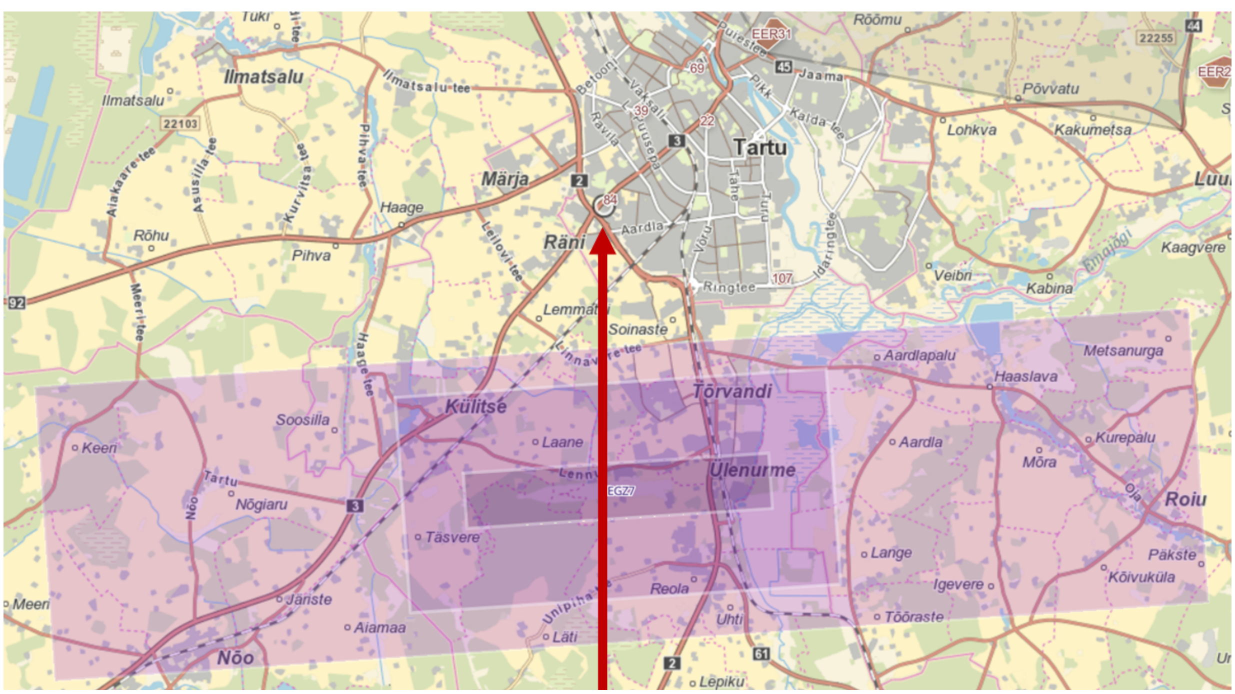

Fig.7: TSP on Estonian Drone Map

- **Area around Estonian Aviation Museum:** It is located at 58.28810036049674, 26.7649243763546. This location could be ideal for the mid-term to perform complex operations between EAVA and the Estonian Aviation Museum. Operations under 50 metres (165 feet) may take place at this location.

Fig.8: Estonian Aviation Museum in Tartu

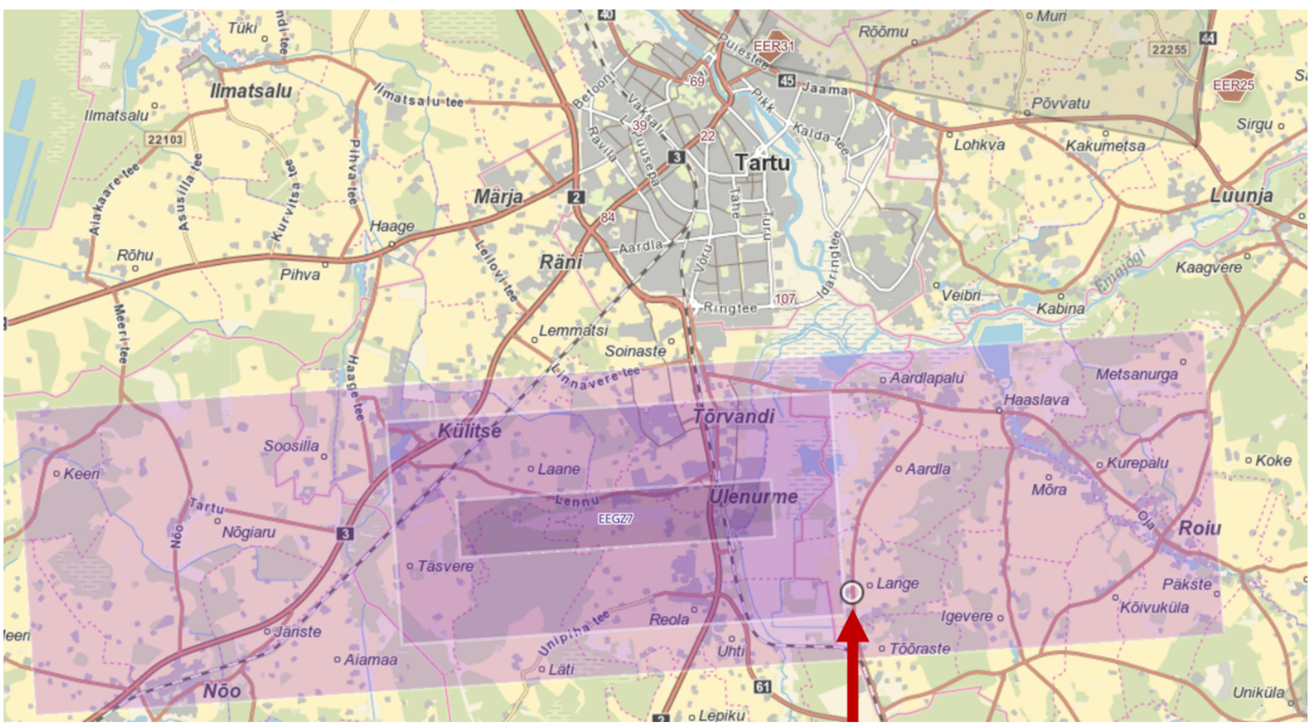

Fig.9: Estonian Aviation Museum on Estonian Drone Map

4.5 Sandbox Operations Center

Based on the proposed locations, the ideal choice for an Operations Center would be at EAVA. The scope of the Operations Center would be the provision of the hardware and software required in the sandbox, ensuring that the scope of the testing proposed by the user is suitable for the sandbox, verifying that the users of the sandbox have the required documentation, including insurance, providing a tour of the facility to the users, and the management of personnel. Therefore, minimum staffing requirements for the Operations Center have to be determined prior to its operation. An Operations Center Manager would be required to manage the facility and ensure the efficient operation of the sandbox. They would also be responsible for managing the personnel at the Operations Center. An Operations Center Controller would be responsible for dispatching, managing, and coordinating the activities pertaining to the movement of UAS, and they would have the authority over controlled support systems. A designated field personnel would be required to assist UAS operations on the field and support the user's operation as deemed necessary.

In order to perform these activities, the Operations Center would require infrastructure such as workstations equipped with access to the internet, meeting rooms, a meteorology station, and potentially a hangar in the future for eVTOL operations in the sandbox.

Software and Hardware Requirements:

Number	**Type**	**Specification**	**Operating System**
6	Pc with FullHD or 2K monitors	8 CPU cores, 8 GB RAM	Windows 11
4	Laptop	Core i7-8650U (4.2GHz), 16 GB RAM	Windows 11
3	Android mobile phone	512 GB Memory 6GB RAM	Android 11
3	IoS mobile phone	512 GB Memory 6GB RAM	iOS 16
6	Mouse	Master MX 2 Mouse or equivalent	NA
6	SIM Card	Nano SIM Card - Estonian Mobile Network Provider	NA

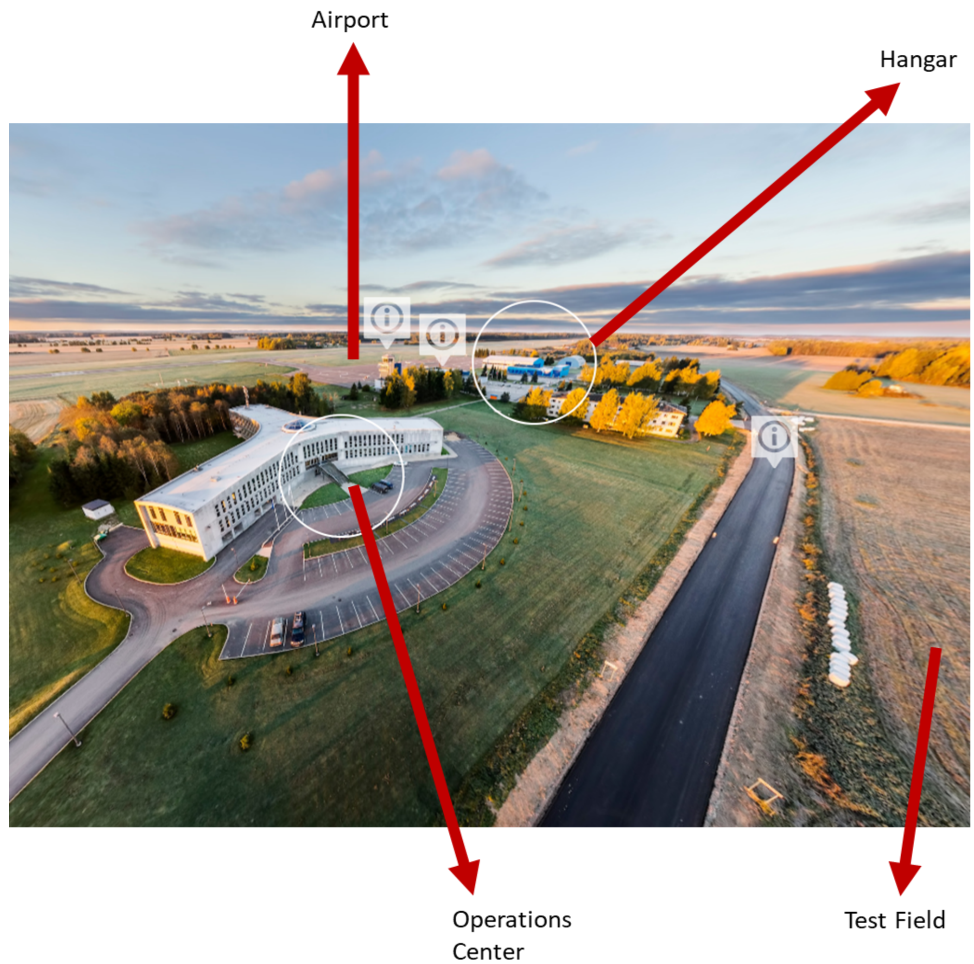

Fig.10: Operations Center at EAVA

Hours of operation would have to be established based on the business model that is determined for the sandbox. Some factors for consideration are training periods, system expansions, qualification period, special events, and contractual obligations. The expected cost would depend on the business model, as well as the technical requirements and the facilities that are provided at the Operations Center.

- **Training periods:** As part of the Operations Center, it is necessary to evaluate the factors that affect the adequate level of staffing to ensure sustainable, safe and efficient staffing levels for the safe management of the system.
- Selection and training of personnel varies greatly and depends on the functional responsibility and the authority level over operational elements.
- The level of effort on selection and training varies through orientations and lecturers, field experience, simulated scenarios and on-job training. It will be necessary to formally document the training program requirements and materials. The training program shall at minimum include:
    - Requirements of the training program, including facility and physical characteristics
    - Goals and objectives of the facility
    - Field training for knowledge on the functional elements

- Workstation operations
- Standard Operating Procedures (SOPs)
- Control and support facilities
- Safety-related practices and functions
- Restoration of service techniques and standardised job practices
- Incident management
- Communication protocols
- Lost link and non conformance management

Upon satisfactory completion of the required training period, the personnel will receive formal certification and qualification in the appropriate category.

It is highlighted that given the dynamic nature of the unmanned aircraft supporting system, personnel in the Operations Center environment must receive retraining or recertification. It should then be necessary to determine the methods and the approaches for such evaluation activities.

- **System expansions:**

  It is important to always consider the life-cycle of the U-space sandbox, and to its Operations Center. As identified in the Action Plan D2.2, the mid-term and the long-term vision is to enable U-space business operations in a national-wide manner and to empower an integrated and highly digitalized national framework to enable the implementation of IAM and UAM services.

  For this reason, it should be taken into consideration the changes in the external environment, new personnel capabilities, and multimodal capabilities necessary to be enabled in the near future.

- **Qualification period:**

  The qualification period is the phase into which all the arrangements are put in place for the correct and efficient operation of the U-space sandbox. The qualification period is divided into:

- **Pre-qualification period.** In this period it is necessary to perform several actions in order to set the basis for the launch of the U-space sandbox. This period includes external and internal activities in order to reach the identified objectives. The external activities include the development and implementation of a digital communication strategy, which comprise the creation of an onboarding web portal, open for information retrieval, qualification rules and for applications from firms and businesses. It is also important to perform activities related to public consultation and outreach, in order to consult the U-space sandbox stakeholders widely and obtain their feedback in a preliminary stage. The internal activities include the finalisation of the core team which will include:
  - Personnel of the operations center of the U-space sandbox.
  - The team, authorities and entities which will be involved in the U-space coordination mechanism explained in section 6.
  - The screening committee which will evaluate the applications received.

Finally, the last activity should include the identification of metrics and KPIs to be evaluated and tracked during the U-space sandbox activities.

- **Application period.** In this period, which typically can last up to 60 days, firms and companies can apply to the U-space sandbox. In order to apply, the eligibility criteria must be clearly understood and accepted, in order to conduct regular activities in the U-space sandbox. It is recommended to encourage innovators from all backgrounds to apply to the U-space sandbox, in order to be able to cover all the different aspects of the European U-space regulation 2021/664, which are mainly divided into three parts: technical, business and tech/business aspects.

- **Application review period.** In this period, which typically can last up to 30 days, the screening committee will review all the applications received, by engaging as appropriate with other expert resources. It is important to conduct due diligence in all the applications received by conducting background checks, company capabilities, company expertees, in order to select finalists for in-person interviews.

- **Sandbox phase**. In this period, which typically can last up to 6 months, the test plans are designed, in accordance with the metrics and KPIs of the pre-qualification phase. The test plans are then accordingly implemented, through specific testing activities in the U-space sandbox. The U-space sandbox testing activities should be, as much as possible, compliant with the automated verification described in section 6.4. Although, it is stressed that not all the U-space requirements from the Regulation 2021/664 can be accomplished through the automated verification framework. The final task should include the review and presentation of the final test results in order to have an appropriate exit plan.

- **Final review.** In this period, which typically can last up to 60 days, revisions to the U-space sandbox framework are conducted accordingly. Recommendations on the framework, selection process, supervision process are discussed accordingly and lessons learnt from the sandbox phase are reported to the public. In this phase it is also conducting a U-space requirements compliance review in order to validate the successful compliance and plan accordingly the new activities.

- **Special events:**

  Special events have to be carefully considered during the implementation and management of the Operations Center. These events might include special activities like other areas around in use, airshows, training flights, new procedures but also special instructions or restrictions like adjacent flights, nonstandard configurations, nonstandard staffing.

  It is recommended that the Operations Center manager employs a checklist which ensures consistency and completeness of the tasks to be carried out.

- **Contractual obligations:**

  During the U-space sandbox implementation, some design features have to be considered. These features will then affect the contractual obligations the firms and businesses will need to comply with. Some of them are related to:

- Limited number of firms and business: sandboxes are usually designed for small scale testing with strict limits on the number of participating customers. The sample set of customers should be sufficient to enable the collection of enough data, and satisfy the desired list of requirements.
- Fit and proper tests: firms and businesses participating in the U-space sandbox could be required to undergo fit and proper assessments to determine whether the individual is capable of performing the function they have applied to test.
- Cost reasonableness: for testing companies, the ROI should be high enough and cost low enough to justify investments in the sandbox.
- Minimum capital requirements: it can be considered to set a minimum liquidity requirement threshold from the participants, this is particularly relevant for USSPs or CISPs. This is linked with the Article 15(c) of the U-space Regulation 2021/664.
- Disclosure: Disclosure may be needed from participating firms and businesses to ensure consumers know the potential gaps when engaging in a sandbox environment.

Based on a poll conducted by ANRA at the Stakeholder Workshop, it was found that stakeholders are most interested in the following design features:

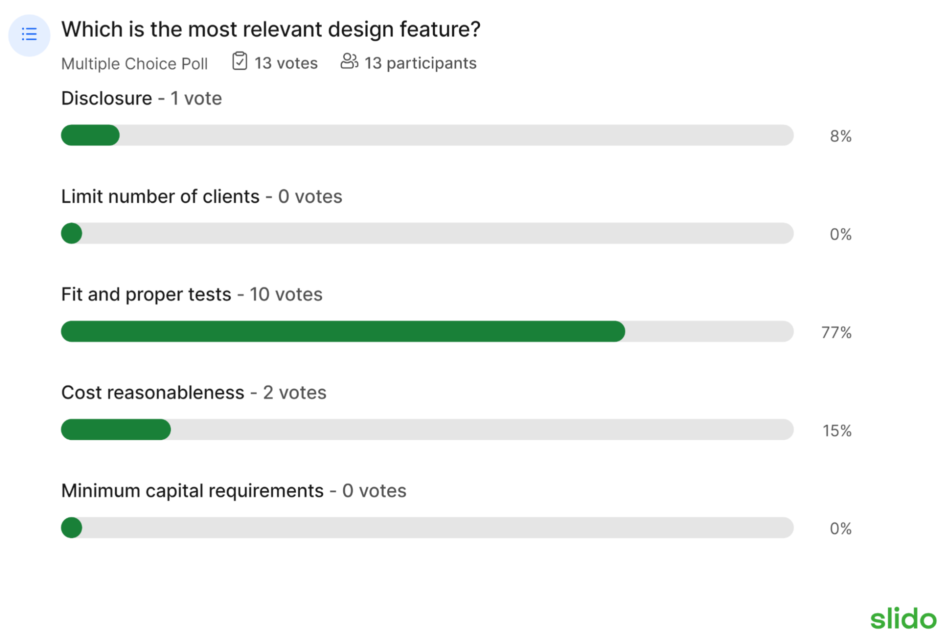

Fig.11: Poll on design features conducted by ANRA Technologies at the CACTUS Stakeholder Workshop

4.6 Correlation between use cases and sandbox locations

Deliverable 2.3 determined the potential use cases that could be conducted at the sandbox. The following table aims to correlate the use cases with the sandbox locations that have been proposed:

1 = Estonian Aviation Academy

2 = Tartu Science Park

3 = Corridor between EAVA and TSP

4 = Estonian Aviation Museum

Use case	Sandbox location(s)
Testing and validating U-space services and design	1, 2, 3, 4
Testing Uncrewed Aerial Vehicle (UAV) systems, flight testing in the open and specific category	1, 3, 4
Testing monitoring solutions and communication tools	1, 4
Testing innovative technologies to mitigate risk in future operations	To be determined based on the innovative technology and the risk associated with the use case
Validating regulatory compliance	1, 2, 3, 4
Developing and validating operating procedures	1, 2, 3, 4
Supporting educational activities, conducting trainings, and practice flights	1, 4
Offering opportunities for strategic partnerships among businesses	1, 2, 3, 4
Testing to obtain waivers, such as regulatory exemptions	To be determined based on the risk associated with the use case

Table 1: Mapping Use Cases to Sandbox Locations

5. Financial Feasibility

5.1 Introduction

A financial feasibility enables stakeholders in understanding how the Estonian sandbox concept could be established, and the appropriate business strategy, so that the sandbox can be positioned such that it will be financially viable and attractive to potential users. Financial feasibility is closely linked with the business model that is established and the use cases that are performed in the sandbox.

5.2 ANRA's methodology to perform the cost-benefit analysis

When performing a cost-benefit analysis (CBA), it is crucial to make assumptions and develop scenarios that are as close as possible to the preferred state. This would ensure that the market analysis is realistic and that the cost-benefit analysis is appropriate for the purpose.

The base scenario for the Cactus Sandbox assumes the competent authority sets up U-space regulatory sandbox challenges aimed at convening the supply-side industry to develop and deliver U-space solutions. Participants will get the benefit of regulatory guidance in return of collaborative solutions development. While participation in the challenge will incur a small cost, the key validation aspects of the regulatory challenge will require the use of sandbox facilities. The financial feasibility study assumes a recipe of sandbox facility charges to support the test ad validation objectives.

The financial feasibility study should include the total cost of running the U-space sandbox allowing for the nature of its setup and the period for which it will be operational. The initial working capital requirements for the key resources and activities would have to be obtained, and an analysis of the most important costs inherent to the business should be assessed. The impact of the sandbox must holistically be assessed and the return on investment, which could be financial or non-financial. The profitability, liquidity, and cash flow can be analysed by assessing the total cost to the revenue generated. Based on this analysis, a recommended approach is obtained and the limitations, associated risks, and benefits may be assessed.

Investments are needed for the long-term growth of the U-space sandbox. Capital expenditure (CapEx) refers to major long-term expenses such as physical assets, fixed assets, and also intangible assets. Some CapEx costs for the sandbox include infrastructure costs, such as physical and digital infrastructure, storage, equipment costs such as IT, and the required intangible assets. Operational expenses (OpEx) are the costs incurred by a company to ensure its daily operations. Some operational expenses for the sandbox could be rent and utilities, development costs, legal fees, insurance, administrative expenses, salaries and personnel costs, and research and development costs. While it is expected that the U-space sandbox is state funded in the short-term, there is potential for it to generate revenue in the long-term based on the business model that is established. The benefits of a fixed pricing strategy as opposed to a dynamic pricing strategy should be assessed to determine the appropriate approach for the sandbox.

With this in mind, the financial feasibility spreadsheet was developed with the express intent of defining the base scenario in which the sandbox facilities support the development and test of U-space systems and drones together with a sandbox charging scheme. A key assumption made was that the sandbox would be an operational test capability where stakeholders can innovate, develop and test systems and drones either in isolation or with integrations with U-space. Please, refer to the D2.1 Annex - Quantitative Financial Feasibility for further information.

5.3 Other methodologies

PwC has developed a framework called Total Impact Measurement and Management (TIMM) that assesses four quadrants, namely costs linked with the economic, social, environmental, and fiscal (tax) dimensions to ensure that the assessment is holistic. In this case, the use cases in the sandbox and what business as usual would look like should be defined as well as the costs associated with them to conduct the financial feasibility analysis.

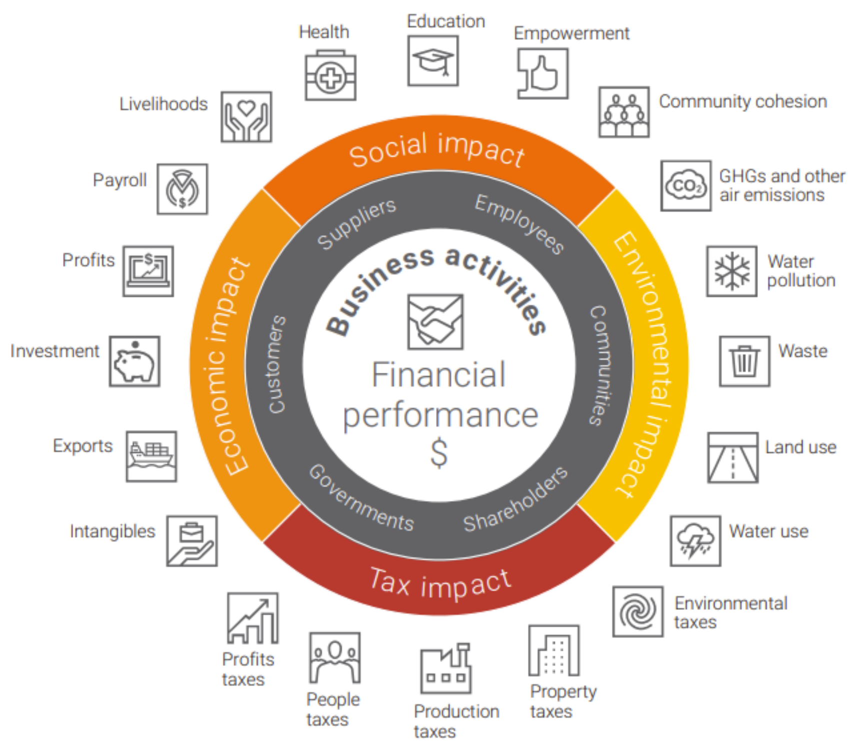

Fig.11: PwC Total Impact Measurement and Management (TIMM) framework

Another means to assess if a project is financially feasible is by obtaining past performance data or past benchmarks of sandboxes (not necessarily aviation) that have been deployed. Items such as sources of financing, capital expenditure, operating capacities, capacity utilization, sales, and profit for other sandboxes could support in defining a baseline for the financial structure of the U-space sandbox. Working capital requirements, such as the total requirements during the initial years of commercial operation, should be assessed. Marketing costs, namely sales prospects based on market assumptions, demand projections, and terms of arrangement for use, among others, should be detailed. This would lead to a funds flow analysis, which can be divided into long term and short term flow. A projected balance sheet can be drawn up based on the underlying assumptions, which would show profitability estimates, cash flow projections, depreciation of assets, etc., which could support in understanding the financial viability of the sandbox. Government incentives would also be required for several years, before the sandbox can be self-sustaining through the revenue generated.

5.4 Market exploitation

The figure below shows the overall drone readiness of G7 countries and other leading nations, while the following figure shows readiness ranking pertaining to drone regulation. The overall drone readiness value is calculated based on the level of enabling drone regulations, level of wealth and business investment, telecom infrastructure coverage and 4G/5G adoption, and the demand from industries that would like to use drones.

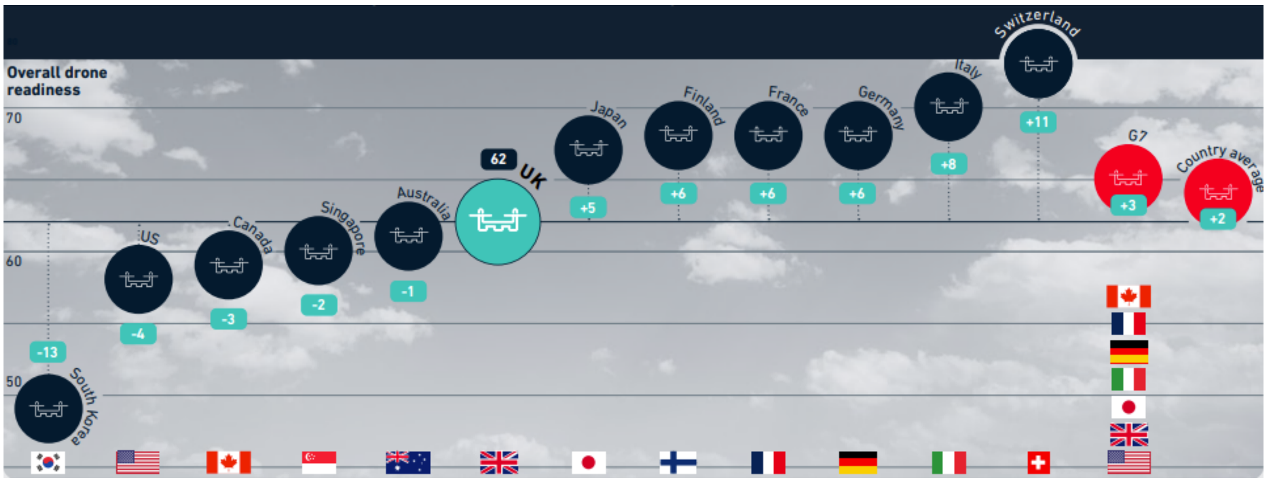

Fig.12: Overall drone readiness (Race to the Top - Assessing and Accelerating Drone Readiness in the UK, the G7 and Other Leading Nations, GSMA Intelligence and BT Group)

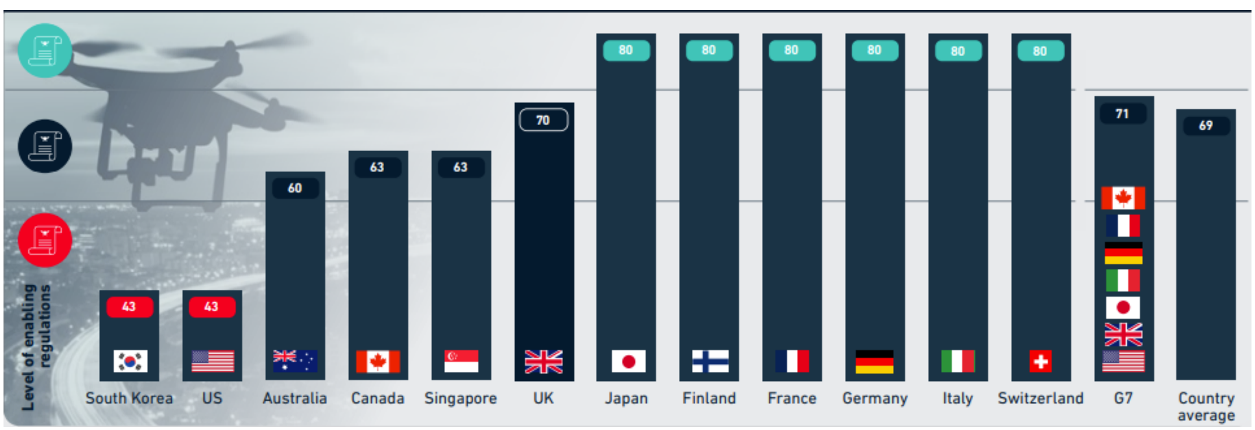

Fig.13: Drone regulation readiness ranking (Race to the Top - Assessing and Accelerating Drone Readiness in the UK, the G7 and Other Leading Nations, GSMA Intelligence and BT Group)

Having the U-space sandbox deployed in Tartu would support Estonia in all factors that were taken into account to calculate overall drone readiness. The sandbox would reduce regulatory arbitrage, enable uptake of the market, and attract investments and further businesses to Estonia. Requests for Information (RFIs) based on specific fundings seeking inputs on the implementation of U-space, such as obtaining information on the maximum operational capacity, can be issued. Companies and consortiums could apply to provide the requested inputs, which could be validated in the sandbox, if applicable. The U-space sandbox is well-positioned, as it can be expanded across Estonia to potentially provide access to the coastline and establish offshore sandboxes, which could be connected via corridors. The ability to operate in uncontrolled airspace with a remote tower is a unique point for the sandbox and data collected from the sandbox could feed R&D activities.

A Living Lab is aimed to be established to conduct ongoing activities after the implementation of the sandbox. Collaboration between the future Living Lab and other sandboxes could be established through cooperation agreements, and information sharing between these sandboxes in other EU countries that aim to implement U-space would expedite the deployment process.

6. Regulatory Compliance

6.1 Applicable regulations

Commission Implementing Regulation (EU) 2021/664, (EU) 2021/665, and (EU) 2021/666 are applicable regulations in the domain of U-space. (EU) 2021/664 establishes a regulatory framework for U-space, (EU) 2021/665 puts forth requirements for ATM/ANS providers when a U-space airspace is designated in a controlled airspace, with regard to coordination between ATS, CISP, and USSPs, as well as information on dynamic airspace reconfiguration, and (EU) 2021/666 describes requirements for manned aviation, in particular the need for electronic conspicuity, when operating in U-space airspace.

In (EU) 2021/664 where a regulatory framework for U-space is established, information pertaining to common information services and common information service providers is described. General requirements for UAS operators, U-space service providers, and U-space services are also established. As U-space service providers and single CISP have to be certified by the competent authority of the Member State to provide services, items pertaining to the application for the certificate, conditions for certification and the validity of the certificate is described. The final articles in (EU) 2021/664 address the obligations and tasks of the competent authorities and the resources that may be required to fulfil these obligations. Acceptable Means of Compliance and Guidance Material to Regulation (EU) 2021/664 on a Regulatory Framework for the U-space describes how the regulatory requirements can be met and complied with.

The establishment of the U-space sandbox will be a first step to support the Transport Administration (TA) in concretely identifying the tasks of the competent authority and the technological and operational capacity required to fulfil these responsibilities as per Regulation (EU) 2021/664. The TA will be responsible for certifying CIS and USSPs, ensuring that the requirements in the regulation are met by the U-space actors, onboarding USSPs before commercial activities are initiated, performing continued oversight activities, and enforcement tasks. In addition, tasks that relate to the effective implementation of U-space, such as system interoperability with respect to data exchange, will also fall under the responsibility of the competent authority.

Coordination mechanism is another crucial task, for which the competent authority is responsible, that aims to coordinate the interests of U-space actors and align activities through each phase of deploying a

U-space. The competent authority is responsible for establishing a suitable mechanism and for nominating a U-space coordinator, who interacts with all stakeholders in order to deploy a U-space airspace in a particular location. If necessary, several U-space coordinators, each addressing a different level of governance, may be nominated. There are three phases associated with the coordination mechanism, namely planning phase, execution phase, and review phase. The nominated U-space coordinator is responsible for addressing each phase according to the coordination mechanism that has been established by the TA in Estonia.

The U-space coordinators are responsible for making recommendations to the competent authority on whether a certain U-space may be designated, based on which the competent authority may recommend it to the Member State for a final decision. In the execution phase of the coordination mechanism, the competent authority (not necessarily the TA, as other authorities may have the authority to do so as well) will be responsible to provide temporary restrictions based on state, emergency, or military (among others) activity that would require a change in the U-space. This could result in a dynamic airspace reconfiguration, establishment of dynamic geozones, or NOTAMs being issued. In the review phase, the competent authority would be responsible for performing a technical review such as ensuring that operational performance indicators are met, safety and security parameters are achieved, and other items which are a part of the oversight process. If the U-space coordinator makes any recommendations on modifying the U-space that is deployed, then the competent authority presents this to the Member State for modification as previously done in the planning phase.

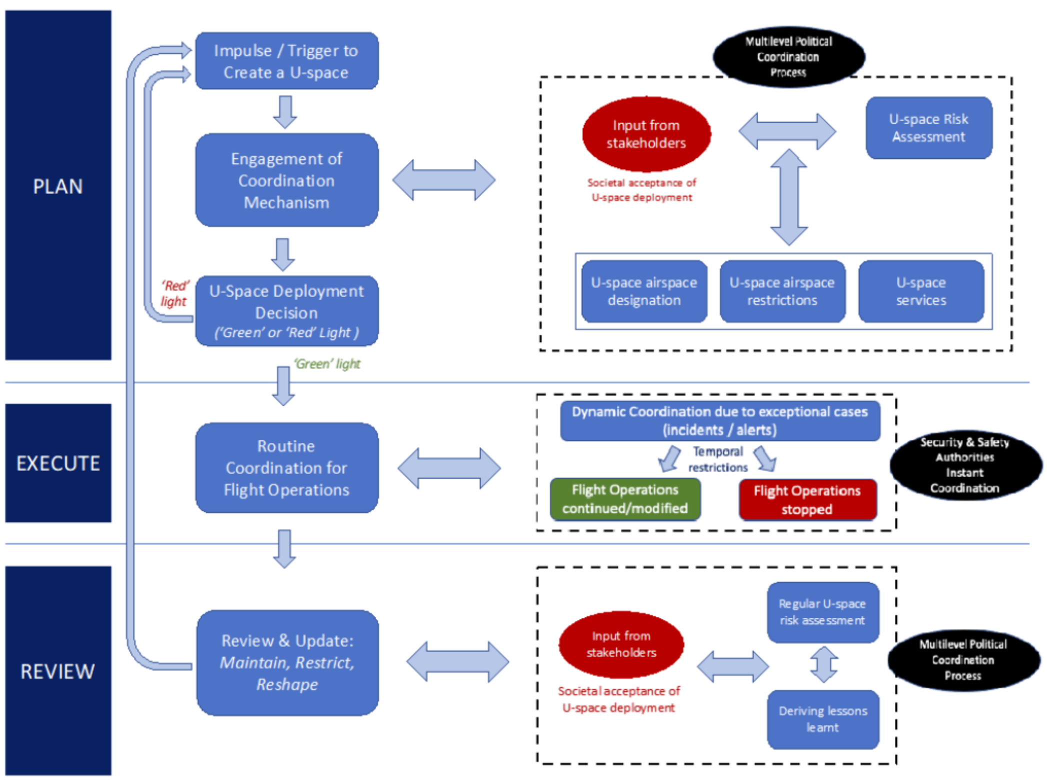

Fig.12: Coordination mechanism - planning, execution, and review phase (Regulation (EU) 2021/664)

6.2 Internal regulations and legal perspective in Estonia

The Estonian Aviation Act is a legal document that provides the basis for flight operations, aviation safety and security. Rules and restrictions for UAS pertaining to the use of Estonian airspace are described in § 4^1, especially in regard to temporary geographical area restrictions. Chapter 7 describes the operation of UAS and aims to enforce Regulation (EU) 2019/947. Registration of the UAS and UAS operator, remote pilot competency, certificate and training, and operational declarations and authorisations for the specific category of operations are described in this chapter. It is imperative to note that the national regulation for (EU) 2021/664 is under development and is expected to be available in 2024.

Other relevant Estonian regulations for UAS include:

- Internal Rules of the Air, which builds on Regulation (EU) 923/2012, which establishes the common rules of the air and operational provisions regarding air navigation services and procedures.
- Government Regulation No. 82, which describes the procedures for establishing a temporary geographical area and notification procedure to restrict the entry of UAS.
- Government Regulation No. 81, which establishes the procedure to apply for a Permit to Fly (state aviation) in restricted areas.
- Government Order No. 229, which establishes flight restrictions and geographical zones to limit the flight of UAS for environmental protection, national security, and public order.
- Government Regulation No. 240, which describes the procedure for using the Estonian airspace and Tallinn flight information area.
- General precept from the Transport Administration, which is a tool to establish ad-hoc requirements for UAS and to establish geographical zones as necessary.

The Estonian Drone Map is a useful tool for UAS operators to view geographical zones that are currently in effect in Estonia. Each UAS geographical zone contains a designator, the altitude for open category and specific category operations, activation period for the area, operational conditions, and detailed information corresponding to each location.

6.3 USSP certification model

Article 14 and 15 of (EU) 2021/664 respectively describe the application process and the conditions for obtaining a certificate in order to provide USS and/or single CIS. The competent authority may only certify USSPs and single CISP that have their principal place of business in the corresponding Member State. The aim of the certification is to assess if the organisation providing these services in a U-space airspace fulfils the requirements listed in Regulation (EU) 2021/664. When initiating the certification process, the USSP or single CISP presents a strategy (possible in the form of a project plan and compliance matrix) and confirms if the scope of the certification is appropriate. Through the course of the certification, the competent authority verifies the presented documentation and audits the organisation to ensure that all the articles in the regulation are complied with. If needed, familiarisation meetings may be organised by the competent authority to understand the various aspects of the organisation that is being certified. Upon certification, the certificate is valid indefinitely provided that the USSP or single CISP conforms with the requirements and the limitations described in the certificate.

Onboarding activities such as validating that the services provided by the USSP satisfies local conditions must be conducted by the competent authority.

6.4 Plan for compliance monitoring

Compliance monitoring is ensured through items related to three different main blocks:

- Business:
  - Compliance matrix: in order to have a clear understanding on the regulation compliance statement, strategy and method for showing the compliance, evidence/deliverable.
  - CONOPS: in order to have a clear understanding on the use cases, functional system involved and boundaries for the operations.
  - Management system: in order to demonstrate technical and operational capacity with adequate resources to perform the different tasks.
  - Business plan: in order to show the financial ability to ensure the tasks execution based on the operational conditions.
- Tech/Business:
  - Safety support assessment: in order to demonstrate that unsafe conditions in the context of U-Space are mitigated to an acceptable level.
  - Information security and software assurance assessment: in order to ensure a consistent level of security and a documented software development process.
  - Emergency Management Plan: in order to ensure safe continuation of operations and appropriate coordination with other organisations.
  - Compliance of USSP and CISP platforms and environment: as required by the Articles 5 and 7 of the EU U-space regulation 2021/664.
- Technical:
  - Compliance with the U-space services requirements
  - Automated verification

Automated verification is a verification and validation practice which can be used in order to assess big amounts of data which will be too complex to manually evaluate.

Due to the fact that U-space is a cloud-based, services-driven technology, based on open software and API standards, the certification of U-space software requires a review of software code, libraries, APIs and data used or accessed by U-space services in real-time or where the service is used to produce safety critical data.

This can be used as a tool for overview and control of functions under responsibility of the CAAs in order to facilitate the confirmation that the software under examination meets the functional, safety, or performance criteria established by the regulation. Automated test environments can be run to test interfaces, IO and connectivity at no additional costs and will be faster than manual testing. Its usage can help reduce the verification and validation efforts on the part of service providers and certification authorities.

The core aspects related to automated verification are:

- Completeness (& Effectiveness): coverage of the performance requirements (e.g. AMCs/standards)
- Representativeness: the tests conditions are sufficiently close to a real operational environment
- Trustworthiness: trust/confidence in the test results (credit)

For this reason an automated verification environment must rely on:

- Clear identification of the limits/suitability of the automated approach
- A defined and documented method/procedures to ensure coverage while developing the test cases/procedures (“stop-criteria”):
    - Granularity and traceability, of the test cases with the requirements
    - Accurate pass/fail criteria (e.g. expected value, behaviour)
    - Review of the test cases & procedures
    - Confidence in the test environment -> qualification