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5G for a Better Tomorrow: Protecting Lives and the Environment in Riga and Turin
Grant Agreement No 101133716

5G4LIVES D3.1_ 5G4LIVES TECHNOLOGIES INTEGRATION CONCEPT

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1.1	15.10.2024	Collection and processing of initial information from all involved Partners
2.0	29.11.2024	Obtaining and structured information regarding solutions and specifications for the Torino Use-Case
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3.1	08.02.2025	Revisions by Partners, obtaining information by Wind3
3.2	13.03.2025	Reviewing and formatting information and sections, as well as formulating conclusions.

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5G4LIVES ABSTRACT

In an era where technology is advancing at an unprecedented pace, the project takes center stage as an initiative committed to harnessing innovation for the greater good. This project unfolds its transformative vision across two distinct geographic clusters, Latvia and Italy. It strategically leverages 5G connectivity alongside cutting-edge technologies such as Unmanned Aerial Vehicles (UAVs or drones) and alternative hydrogen power. With a dual mission of enhancing public safety and environmental health, the project unfolds a narrative where data-driven forecasting and real-time aerial situational awareness become the bedrock of a more secure, efficient, and sustainable future.

At its core, the project seeks to enable optimal emergency management and data-driven forecasting, a mission encompassing public safety. Through the dynamic fusion of 5G connectivity and UAVs, this initiative aims to provide real-time aerial situational awareness and automatic vulnerability assessment for at-risk areas. The project's scope extends beyond traditional rescue operations, pushing the boundaries of innovation to safeguard both human lives and the environment.

The project in Latvia involves using drones and 5G technology for monitoring and rescue operations, especially at Vecaku Beach and Kisezers Lake in Riga. This approach aims to enhance police efficiency, particularly in challenging terrains. Turin focuses on developing a 5G-enabled service for situational awareness and vulnerability assessment to counter natural disaster threats. This includes testing anti-drone hacking technology, integrating satellite data, and improving pilot-drone command for better emergency response. The project also includes research in Riga on safety protocols and procedures for urban drone operations and beyond-visual-line-of-sight (BVLOS) flight methodologies with EU-wide relevance. A significant aspect of the project is to engage in extensive communication to inform and educate local, national, and EU networks about these technological solutions.

By leveraging 5G and drones, the project promises quicker and more effective emergency response, addressing staff shortages in law enforcement and expanding their skill set. In Latvia, the use of drones and 5G connectivity will empower law enforcement to intervene more swiftly, addressing staff shortages, and expanding the skill set of police officers. In Italy, the project will mitigate the threat of natural disasters and test innovative anti-drone hacking technologies, leading to more efficient emergency responses. Additionally, developing safety protocols, and procedures for urban drone flights, and validating BVLOS flight methodologies will set new standards for public safety and security. The project emphasises community involvement and knowledge sharing, ensuring that the benefits of these technological advancements extend beyond immediate emergency management to foster a more resilient and informed society.

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ABBREVIATIONS AND ACRONYMS

AI	Artificial Intelligence
BVLOS	Beyond Visual Line of Sight
CO_2	Carbon Dioxide
CV	Computer Vision
ENAC	Ente Nazionale per l'Aviazione Civile (Italian Civil Aviation Authority)
EU	European Union
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
KPI	Key Performance Indicator
LTE	Long-Term Evolution
MW	Microwave
ML	Machine Learning
ROCC	Remote Operation Control Centre

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TMA	Tower Mounted Amplifier
TDD	Time Division Duplex
UAS	Unmanned Aerial System
UTM	Unmanned Traffic Management
UAV	Unmanned Aerial Vehicle
5G NR	5G New Radio
5G SA	5G Standalone
5G4LIVES	5G for Lifesaving and Emergency Services
VMS	Video Management System

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EXECUTIVE SUMMARY

The present deliverable D3.1 is the result of work carried out within Task T3.1 - 5G, UAV technologies advancement to fit the project concept, and Task T3.2 - Extension of specific platforms and tools for monitoring and controlling tasks performance of the 5G4LIVES project, as well as the outcomes of WP2 – Deliverables 2.1 / 2.2 - technologies analysis, regulatory framework, use case descriptions, and a study on the essential minimum requirements for 5G mobile network coverage. The results of Deliverable 4.1 - Demonstration across technologies and scenarios also contribute to this report.

The document presents the technical and operational analysis results of scenarios and key technology requirements for the Turin and Riga use cases, forming the 5G4LIVES platform. It includes detailed technical requirements for monitoring system components, including UAVs, supporting infrastructure, necessary software, and formulated workflow processes for platform operations. Additionally, the document provides a technical description and specifications for 5G network deployment, which serves as one of the key components of the 5G4LIVES ecosystem.

Significant progress has been made in system design for both UAVs and 5G infrastructure, improving real-time connectivity, automation, and mission control. This work goes beyond industry standards, introducing UAV integration strategies and 5G-driven monitoring solutions supporting BVLOS operations. The document also includes analysing alternative power supply components to reduce environmental pollution.

Tactical KPIs for assessing lifeguard work efficiency have been defined, alongside an action plan detailing the interaction between UAV operators in the remote operation center and lifeguard staff at locations where lifeguard services are deployed.

The project consortium has also analysed general approaches for assessing the economic impact of the 5G4LIVES platform deployment, formulating impact assessment principles for drone operations. The deliverable defines key action plan considerations for environmental impact and costs, incorporating circular economy principles and best practices.

The document consists of five parts:

1. 5G Integration – presenting solutions and specifications for 5G network deployment for use cases in Riga and Turin locations.
2. UAV Integration—Detailing and justifying drone integration solutions, considering the developed use-case scenarios, along with technical specifications and requirements, including supporting systems necessary for UAV operations.
3. 5G4LIVES Lifeguard Platform – outlining the principles of lifeguard service organisation and the general design of the 5G4LIVES platform in the context of establishing an operational system.
4. 5G4LIVES Operations Environment – presenting solutions for BVLOS drone operations and analysing green technology implementation and impact assessment principles.
5. 5G4LIVES Lifeguard Action Plan – containing tactical KPIs for new lifeguard services and an action plan describing the workflow, procedures, and operational principles of the 5G4LIVES platform, along with an integration plan.

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INTRODUCTION

The 5G4LIVES project is advancing the integration of 5G connectivity, UAV technology, and lifeguard operations to create a more effective, automated, and responsive system. This deliverable, D3.1, provides an in-depth assessment of the technological and operational advancements within the project, particularly focusing on system integration, operational workflows, and impact assessment methodologies.

The purpose of this document is to provide a detailed overview of the technical, operational, and other solutions of the 5G4LIVES concept for integration and ecosystem development. Following the results of Task 4.1 and WP2, and considering the outcomes of the preparation of demonstrations, this deliverable includes solutions for expanding the existing system to create a monitoring system. The results are aligned with T3.1 and T3.2. The specific objectives of this Deliverable were:

- Advancing 5G and UAV technologies to align with the project concept.
- Extending specific platforms and tools for monitoring and control task performance.

The results of this Deliverable serve as the primary technical and operational specification of the 5G4LIVES platform, as well as a framework for specific workflows, procedures, and principles of system, users, and solution interactions. In D3.1, methods such as technology analysis, scenario modeling, and impact assessment were applied, along with approaches from best practices of related EC initiatives and projects. The formulation of technical characteristics and operational indicators for developing specifications was based on requirements, constraints, assumptions, scenarios, and use cases defined within the relevant WPs and Deliverables of the 5G4LIVES Project.

The deliverable outlines several core components of the integrated 5G4LIVES system, including:

- 5G and UAV integration, ensuring advanced connectivity, control, and high-reliability operations.
- Lifeguard work efficiency performance, where drones assist in routine surveillance, incident detection, and real-time guidance for rescue operations.
- Advanced BVLOS capabilities enable lifeguards and remote pilots to operate drones remotely via advanced connectivity, reducing response times while maintaining safety compliance.
- Smart location monitoring, leveraging UAVs for continuous area surveillance, real-time emergency alerts, and automated intervention strategies.
- A structured Lifeguard Action Plan, integrating UAV workflows into existing emergency protocols, with decision-making support models, situational awareness tools, and optimised response coordination.

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1. 5G INTEGRATION

Integrating 5G technology in the 5G4LIVES project is a cornerstone of its operational effectiveness, ensuring ultra-reliable, low-latency communication between UAVs, remote pilots, and emergency responders. 5G networks provide the necessary infrastructure to support real-time video streaming, automated drone control, and BVLOS (Beyond Visual Line of Sight) operations, which are critical for lifeguard and rescue missions, per 5G4LIVES ecosystem design. Unlike traditional communication methods, 5G's capabilities allow for dedicated connectivity with appropriate quality of service, ensuring uninterrupted and sustainable drone operation in designated environments. Implementing 5G network coverage expansion, near real-time data communication, and remote ID capabilities further enhances situational awareness and automated decision-making processes. Through this integration, lifeguards, emergency services, and UAV operators gain access to a highly efficient, interconnected system, capable of reducing response times and optimising resource allocation in critical rescue scenarios.

This section includes a detailed description of technical solutions for 5G integration, the network deployment strategy, connectivity diagrams, and technical specifications of components for both 5G4LIVES Use-Case locations—Turin and Riga.

1.1. Network architecture

1.1.1. Riga Use-Case 5G network architecture and solution

Frequency and network specification

To successfully deploy 5G-enabled remote drones and UAVs (Unmanned aerial vehicles) for the Riga Use-Case (Kisezers and Vecaki), a mobile network infrastructure must support near real-time communication, control, and data exchange. UAV drones have specific operational requirements that demand high-speed, low-latency, and reliable connectivity. 5G technology offers significant advantages, providing the necessary bandwidth, ultra-low latency, and high reliability to handle the continuous data stream that drones generate while operating in real-time. LMT (Latvian Mobile Telephone) has a broad frequency portfolio, enabling it to utilise various frequencies to support UAV operations. These frequencies span from low to high spectrum, allowing for diverse use cases based on coverage, data rate, and network demand. Here are the frequency bands that LMT can leverage to operate drones efficiently (frequencies are listed as whole band):

- n28 (700 MHz: 703-748 / 758-803). This low-band frequency provides extensive coverage with better signal penetration through obstacles such as buildings and trees. It is ideal for providing wide-area connectivity, ensuring reliable connections for drones operating over large, remote areas like Kisezers and Vecaki.
- n20 (800 MHz: 791-821 / 832-862). Like n28, this band is well-suited for providing coverage in rural or suburban areas, helping ensure that drones maintain a stable connection even in less populated regions.
- n8 (900 MHz: 880-915 / 925-960). This low-band frequency offers improved signal coverage and network reliability. It can support drone operations in urban environments and areas where interference from other wireless signals may be more prominent.
- n75 (1500 MHz: 1432-1517). This frequency band provides only downlink.
- n3 (1800 MHz: 1710-1785 / 1805-1880). This mid-frequency band offers high capacity, which is essential for handling dense communication traffic from multiple drones. It ensures that drones maintain a stable connection, even in high-density environments like cityscapes.
- n1 (2100 MHz: 1920-1980 / 2110-2170). This is a high-capacity band that supports large data transfers. It is particularly useful for high-speed data exchange applications, such as real-time video streaming or large data files sent from the drones to the control center.
- n40 (2300 MHz: 2300-2400). This high-band spectrum offers excellent data throughput, enabling fast and responsive communication for data-heavy applications. It is ideal for supporting drone operations that involve large amounts of real-time data, such as drone fleet coordination and streaming from onboard cameras.

- n7, n38 (2600 MHz: 2500-2690). These bands offer high data rates and excellent capacity for handling multiple drones operating in the same area. They will provide fast communication between drones and control centers, especially in more densely populated regions.
- n78 (3500 MHz: 3300-3800). The n78 band, one of the most widely used for 5G, provides significant bandwidth for high-speed, low-latency communication. This band will be central in deploying the 5G4Lives Riga Use-Case project. It is especially suitable for environments with high-density drone activity, as it offers excellent data throughput and latency critical for UAV operations.

Currently, most of these frequency bands are still being utilised by legacy technologies like 2G and 4G, but plans are in place to re-farm these frequencies to accommodate 5G networks shortly. The transition from older technologies to 5G will unlock the full potential of these bands for drone operations, offering greater bandwidth, lower latency, and higher reliability. For the initial phase of the 5G4Lives Riga Use-Case project, the focus will be on using the n78 band, which will be deployed in both Standalone (SA) and Non-Standalone (NSA) modes. In SA mode, the 5G network will operate independently, providing the full benefits of 5G, including ultra-low latency and high throughput. On the other hand, NSA mode will leverage existing 4G infrastructure alongside 5G, enabling a smoother transition while offering some of the advantages of 5G. Initially, the project will not implement network slicing. This technology divides the network into virtual segments, each optimised for specific use cases (e.g., one slice for UAV control, another for video transmission). However, if slicing technology is introduced in LMT network in the future, it will significantly enhance the network's ability to support the different needs of UAV operations, ensuring that high-priority communications, such as safety-critical signals, are given the necessary network resources.

Frequency specification of n78:

- **n78** is a FR1 (Frequency Range 1) 5G NR band operating in the 3300-3800 MHz range. It employs Time Division Duplexing (TDD), a mode that utilises the same frequency band for both uplink (UL) and downlink (DL), which helps improve spectrum efficiency and reduce latency.
- LMT portfolio has different spectrums:
    - **3400-3450 MHz**, cells are configured with **40 MHz bandwidth**,

  ARFCN = **628666**, central frequency is **3429.99 MHz**;
    - **3650-3700 MHz**, cells are configured with **50 MHz bandwidth**,

  ARFCN = **645000**, central frequency is **3675.00 MHz**;
    - **3750-3775 MHz**, cells are configured with **20 MHz bandwidth**,

  ARFCN = **650834**, central frequency is **3762.5 MHz**;

  These are strictly allocated for 5G network use, ensuring optimal performance for UAV applications.
- Subcarrier spacing for n78 is **30 kHz**, a standard for 5G FR1 (low and mid-range frequencies). The frame structure is defined as **DDDSU**, and cannot be altered.
    - For the n78 40 MHz TDD cell, the theoretical DL maximum throughput for the users is ~506 Mbps, and the theoretical UL maximum throughput for the users is ~166 Mbps. Latency is around ~**10-20 ms**.
    - For the n78 50 MHz TDD cell, the theoretical DL maximum throughput for the users is ~634 Mbps, and the theoretical UL maximum throughput for the users is ~209 Mbps. Latency is around ~**10-20 ms**.
    - For the n78 20 MHz TDD cell, the theoretical DL maximum throughput for the users is ~243 Mbps, and the theoretical UL maximum throughput for the users is ~80 Mbps. Latency is around ~**10-20 ms**.

However, several factors can impact signal quality, throughput, and latency, including competing signals, electromagnetic interference, and environmental conditions. The distance between the transmitter and receiver can also affect signal strength, with longer distances leading to weaker signals. Physical obstacles such as buildings, terrain, and weather conditions can degrade signal quality. The type and quality of antennas, cables, and receivers are also critical in maintaining optimal performance, ensuring that drone operations remain reliable and secure. In summary, the 5G-enabled infrastructure for UAVs in Riga's Kisezers and Vecaki Use-Case will rely heavily on efficiently utilising frequency bands like n78 and others. This infrastructure will ensure that drones can operate safely and efficiently, with the flexibility to scale as more advanced 5G technologies, such as network slicing, are introduced.

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1.1.2. Turin Use-Case 5G network architecture and solution

To support Protezione Civile in the 5G4LIVES project, WindTre will deploy a movable Base Station on Turin's hillside, near the summit, to provide dedicated 5G coverage in the project area.

Within the WindTre network, the deployment will incorporate Remote Radio Units (RRU), capable of supporting multiple radio access bands and technologies. These RRUs will be installed as close to the antenna to optimise radio performance, provided structural verification permits it. The WindTre network will leverage advanced MIMO (Multiple Input Multiple Output) techniques, including:

- 4T4R and Massive MIMO (MMIMO) configurations.
- Active 5G antennas, combiners, and TMA (Tower Mounted Amplifiers).
- A default tilt configuration with separate tilt values for low-band and high-band frequencies.

Network Connectivity.

A Microwave (MW) link will be deployed for backhaul connectivity as the optimal and most efficient solution for connecting the movable BTS to the core network. This approach is particularly advantageous in remote locations where sudden events require real-time monitoring and control.

Key advantages of MW links:

- Protected, redundant, and high-capacity connectivity.
- Faster to deploy compared to fiber optic solutions.
- Cost-effective while maintaining reliability and efficiency.

Network Architecture Overview.

The following diagram (Figure X) illustrates a high-level architecture for the 4G/5G mobile network that will be used in the project.

- The continuous line represents User Plane traffic.
- The dotted line represents Control Plane traffic.

For simplicity, only the main functional network elements are shown in the diagram.

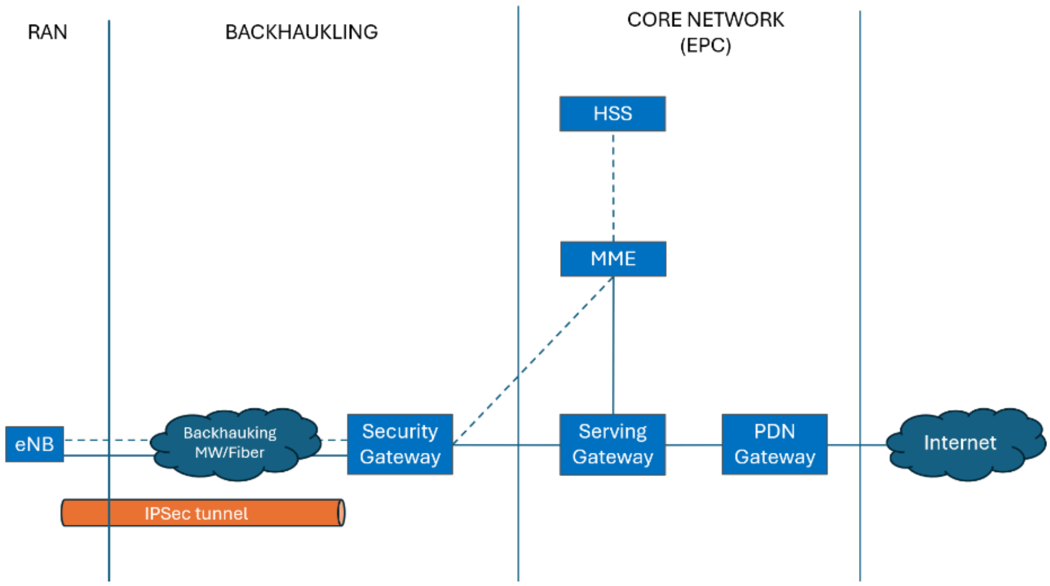

Figure 1. 4G/5G mobile network high level architecture.

Figure 1. 4g/5g mobile network high level architecture.

5G Deployment Solution

The solution will consist of a van specifically equipped with:

- A telescopic pole for mounting 5G antennas.
- A parabolic antenna for backhauling via a radio link.

Base Station (BTS) Configuration

The BTS will be configured with two sectors oriented at 250° and 330°, supporting the following bands:

- 4G: 1800 MHz, 2100 MHz, and 2600 MHz.

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- 5G: N38 and N78 bands.

The antennas will be installed at a height of approximately 16 meters.

1.2. User Equipment connectivity specification

Riga Use-Case

The diagrams describe the connectivity of a 5G-enabled remote drone operation system for Riga Use-Case (Kisezers and Vecaki), considering infrastructure and data communication aspects for automated UAV missions. This system ensures centralised control, real-time monitoring, and data exchange/emergency decision support for search and rescue operations through 5G network architecture.

Figure X describes the Remote Operation Control Centre, the central hub for UAV mission planning, Scenario management, drone operation, and cross-platform real-time monitoring. This facility has the Drone Control & Operations System, which enables remote operators to manage UAV missions using 5G connectivity. The control centre infrastructure is linked to field operations through 5G networks, ensuring almost real-time communication, control, and data exchange. The connectivity extends to other video-based monitoring infrastructure and systems, allowing seamless coordination with emergency services / S&R, or municipal police. The 5G network capabilities ensure that drone commands, telemetry data, and high-resolution video streams are transmitted in almost real-time, allowing immediate situational awareness and decision-making.

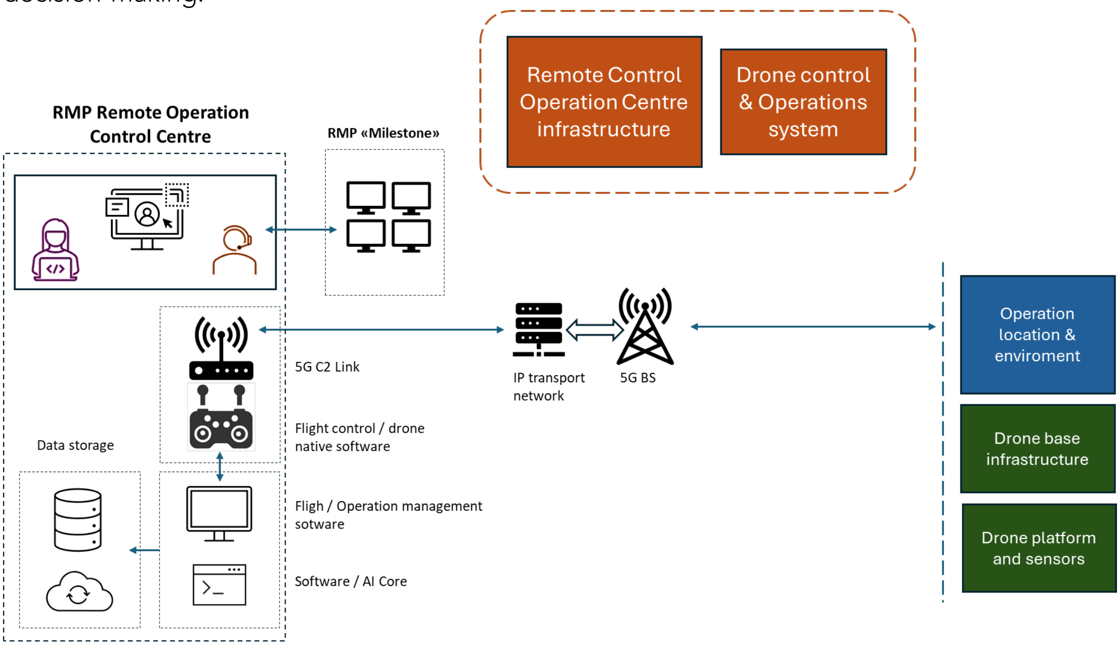

Figure 2. Remote Operation Control Centre connectivity architecture

Figure 2 reflects the remote operations location, where the drone docking station and related operation infrastructure are deployed. This system component is crucial for UAV operations services, providing dedicated battery recharging, routine operation servicing, and automated mission deployment. The drone docking station is a hub where UAVs are placed, recharged, and relaunched, ensuring continuous operations. The 5G network enables direct communication between the docked drones and the control centre, allowing mission updates, software adjustments, and system diagnostics to be carried out remotely. This setup also facilitates remote re-tasking of drones, where UAVs can be reassigned to different missions based on real-time needs.

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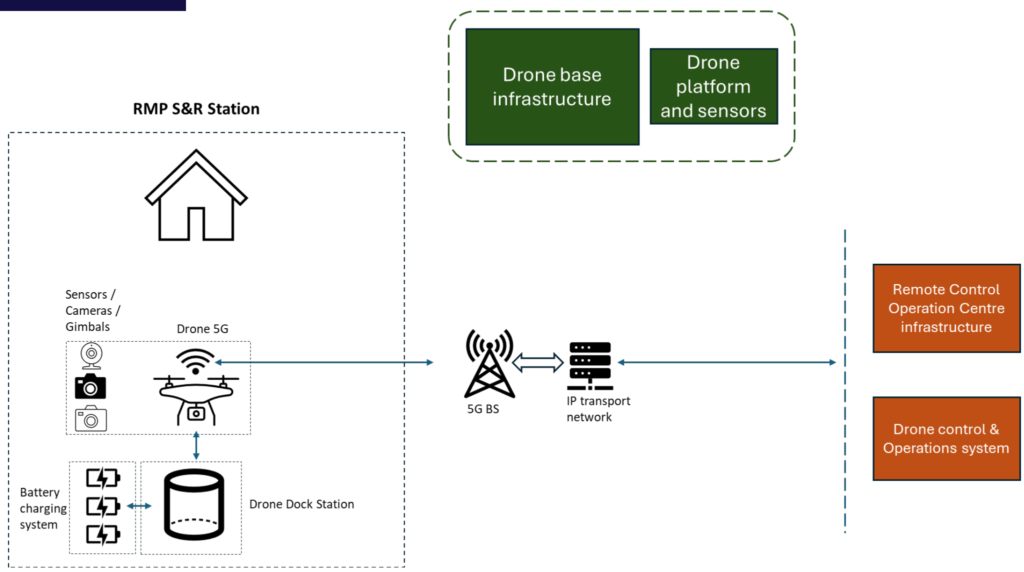

Figure 3. Remote Operation Location/drone base infrastructure connectivity architecture.

The Figure 3 provides a general view of operational connectivity, where drones are controlled remotely from the Remote Operation Control Centre via 5G communication. This architecture ensures real-time bidirectional communication between the control centre and UAVs, supporting command execution, live data streaming, and mission optimisation. The search and rescue personnel operating in the field are equipped with 5G-connected mobile devices, enabling them to receive live video feeds and situational data directly from the UAVs. This situational awareness allows rescue teams to make informed decisions, improving the efficiency of their response efforts. The drone operates automatically, executing pre-defined scenario-based programs, which ensures precision, efficiency, and adaptability in dynamic environments. The 5G network's capabilities support multiple simultaneous drone operations, allowing for large-scale automated fleet management. The UAV automated flight, real-time data streaming, and seamless remote control enable a highly effective and responsive operational framework, acting as a complex decision-support tool.

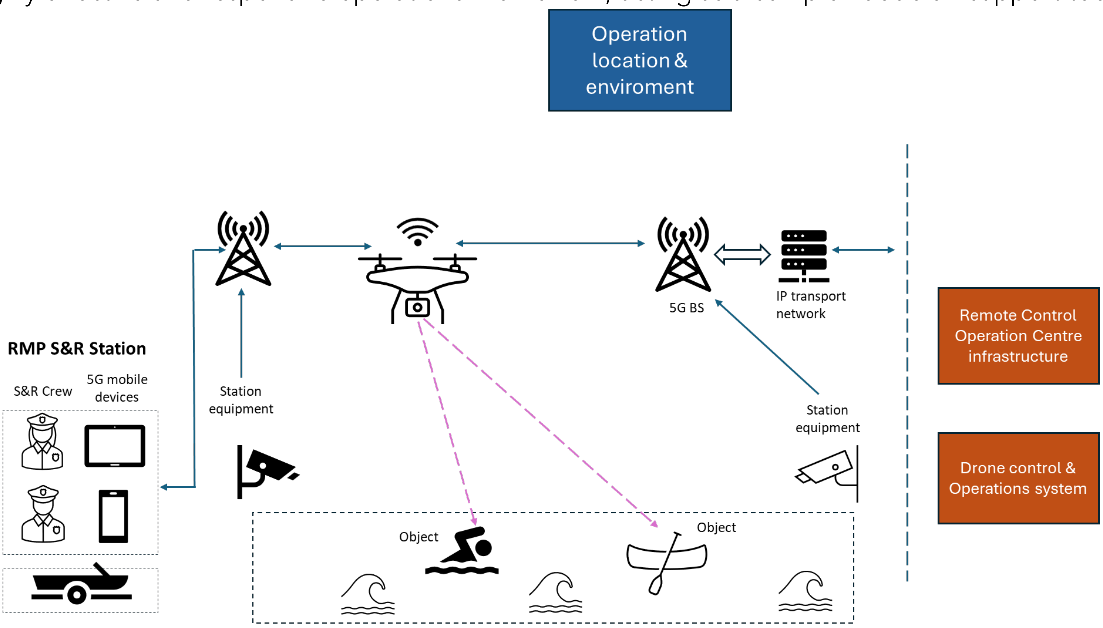

Figure 4. Remote Operation connectivity architecture.

Turin Use-Case

The 5G4LIVES project will develop two use cases around the Turin hillside.

First use case: quadcopter drone for real-time video streaming of an emergency in BVLOS and/or EVLOS.

As discussed in D2.1, this use case evaluates a scenario requiring prompt action due to sudden events, such as high forest fire risk and large-scale urban fire risk. Thus, a quadcopter is exploited to provide real-time

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video streaming for surveillance and monitoring tasks. The architecture adopted in this use case is depicted in Figure 5.

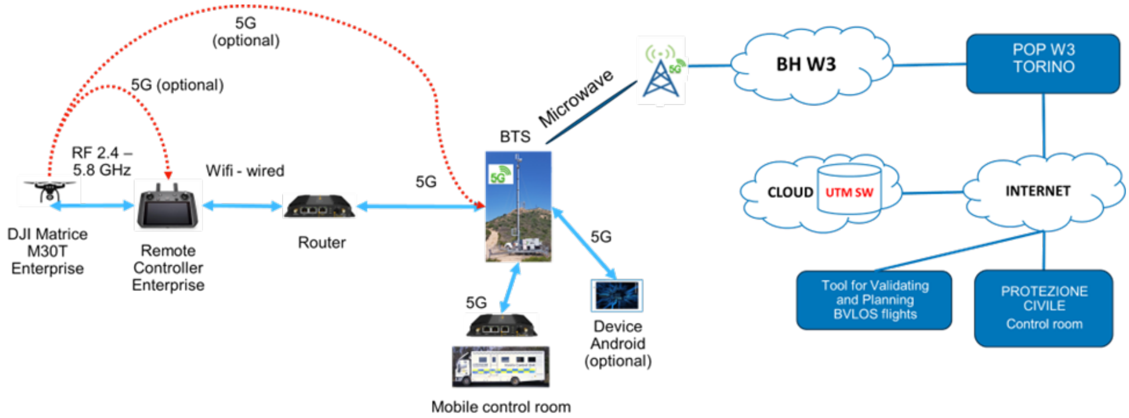

Figure 5. The main connectivity architecture adopted for the 1st scenario of the Turin use-case.

UAV platform connectivity design

The architecture adopted to connect the drone, and all the other equipment is depicted in Figure x.

The drone is connected to the mobile network (4G/5G) with two possible configurations, which depend on the availability of the 4G/5G Dongle to be equipped on the DJI Matrice 30T drone:

- Option 1: The drone is connected to the Internet via the Remote Controller. The drone is directly connected to the remote controller using a radio frequency connection. Then the remote controller is connected to a router that enables the connection to the 5G mobile network via the BTS.
- Option 2: The drone is directly connected to the 4G/5G mobile network using a specific 4G/5G dongle.

Nowadays, the DJI Matrice M30 is equipped with a 4G dongle that enables the drone to communicate directly with all the other equipment and the Protezione Civile control room. Other connected devices are the Mobile Control Room and an Android Device, which Protezione Civile agents use to monitor the flight mission locally.

As detailed later, the Control Room will use the DROMT platform (as UTM SW) to monitor and manage the BVLOS flight, control the drone, and manage the acquired data.

The Politecnico di Torino developed an additional tool for validating and planning BVLOS flights. As detailed in the next sections, this tool will be implemented (currently under development) as a web app that UAS operators can use and then implemented by the Protezione Civile. In particular, this tool will be integrated with the DROMT platform.

Scenario-based components definition:

- Drone: unmanned aerial vehicle
- Controller: radio control equipment used to fly and control the drone
- Router: This connects the radio controller to the UMT SW system via a 5G mobile network. Main specifications: 5G modem, LAN/WAN interfaces, Wi-Fi 6, GPS, external Wi-Fi/cellular/GPS antenna support, up to 1Gbps throughput
- UTM SW: On-Cloud software to manage and monitor BVLOS flight. This element is based on the DROMT Platform
- BTS: to provide 5G coverage within the test area, BTS will have two sectors oriented at 250° and 330°, BBU/RRU/active antennas for supporting 4G 1800-2100-B38 bands and 5G N78 band, with an antenna height of approximately 16 meters
- Backhauking: MW link @ 18GHz, Channel spacing: 112MHz, Configuration: 4+0 XPIC, Capacity (theoretical): up to 4 Gbps
- EPC (Evolved Packet Core): to carry traffic toward the Internet, usually including main functional elements like:
    - HSS (Home Subscriber Server)
    - MME (Mobility Management Entity)
    - Serving Gateway

- o PDN Gateway (Packet Data Network Gateway)

The following will detail some components: the drone, remote controller, ground control system software, UTM software, and BVLOS planning and validation tool.

Second use case: BVLOS flight of a fixed-wing drone for monitoring and risk assessment.

This use case evaluates a scenario in which periodic monitoring is required to provide a risk assessment. For this task, the drone selected Is the AgEagle Ebee X, a fixed-wing drone suitable for monitoring tasks and with an endurance of 90 minutes flight. The architecture adopted in this use case is depicted In Figure 6.

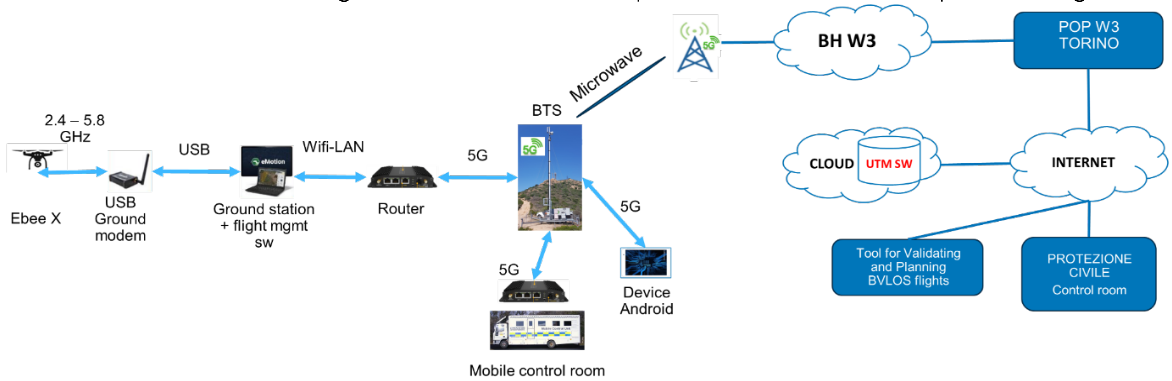

Figure 6. The main connectivity architecture adopted for the 2nd scenario of the Turin use-case

Scenario-based components definition:

- Drone: unmanned aerial vehicle
- USB Ground Modem: ground modem used to connect the drone with the ground station
- Ground Station: equipment to manage and control the drone using the flight management software provided by AgEagle.
- UTM SW: On-Cloud software to manage and monitor BVLOS flight. This element is based on the DROMT Platform
- Router: connecting the radio controller to the UMT SW system via 5G mobile network. Main specifications: 5G modem, LAN/WAN interfaces, Wi-Fi 6, GPS, external Wi-Fi/cellular/GPS antenna support, up to 1Gbps throughput
- BTS: to provide 5G coverage within the test area, BTS will have two sectors oriented at 250° and 330°, BBU/RRU/active antennas for supporting 4G 1800-2100-B38 bands and 5G N78 band, with an antenna height of approximately 16 meters
- Backhauking: MW link @ 18GHz, Channel spacing: 112MHz, Configuration: 4+0 XPIC, Capacity (theoretical): up to 4 Gbps
- EPC (Evolved Packet Core): to carry traffic toward the Internet, usually including main functional elements like:
    - o HSS (Home Subscriber Server)
    - o MME (Mobility Management Entity)
    - o Serving Gateway
    - o PDN Gateway (Packet Data Network Gateway)

The following will detail some components: the drone, remote controller, ground control system software, UTM software, and BVLOS planning and validation tool.

User Equipment connectivity specification

Routers and Android devices are directly connected to the public Wind Tre 5G network using W3 USIM. Regarding the drone, the C2 link's safety aspects include performance requirements, security provisions, and spectrum protection, with Service-Level Agreements (SLAs) at this moment in Italy, due to Italian laws and regulations, it's impossible to guarantee. So, the 5G network will mainly connect the ground control station or radio-command to the flight control platform. Only the DJI Matrice M30 is equipped with a 4G Dongle that can be used to connect the drone with the Mobile network instead of using the traditional RF connection with the Remote Control

1.3. Network deployment

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Riga Use-Case

Flight Plans and Planned Coverage

To successfully provide n78 coverage, the existing LMT infrastructure will be utilised. Currently, modifications are planned for the following base stations:

Table 1. Plan of modification for LMT base stations for 5G4LIVES network deployment.

	SITEID	BS name	Azimuth	Plan	Latitude	Longitude
1	963	Jaunciems	0 / 120 / 240	Add new 3x n78 antennas on 38m at 0, 120 and 240 degrees.	57.046907	24.171218
2	624	Ķīšezers	50 / 290	Add a new 1x n78 antenna on 41m at 50 degrees. Reuse existing 1x n78 antenna on 41m at 290 degrees.	56.995905	24.177666
3	1208	Suži	220	Add a new 1x n78 antenna on the 67m at 220 degrees.	57.02152	24.22506
4	979	Treiliņu	200 / 320	Reuse existing 2x n78 antennas on 61m at 200 and 320 degrees.	57.068621	24.101425
5	1453	Trīsciems	20 / 140	Add new 2x n78 antennas on the 36m at 20 and 140 degrees.	57.0513618	24.128345
6	952	VecākuSt	320	Add a new 1x n78 antenna on the 36m at 320 degrees.	57.0753814	24.1165101

For 5G coverage we can use the **base station Treiliņu**:

Figure 7. Vecaku beach, BS Treiliņu network coverage plan zone

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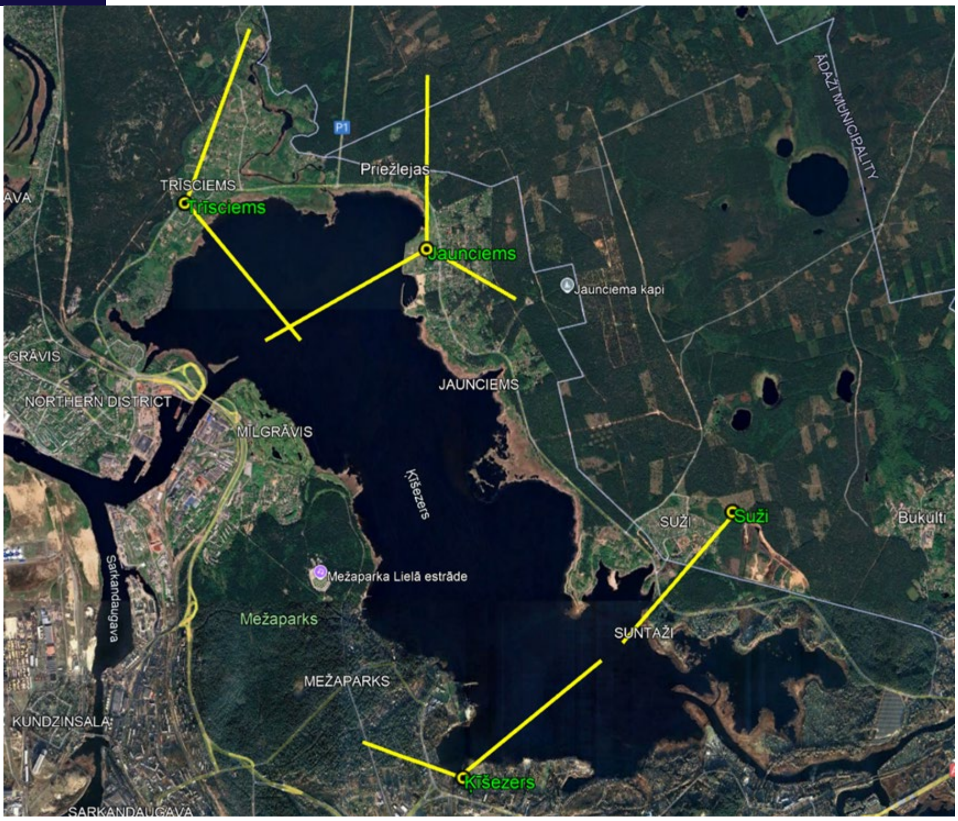

Figure 8. Kisezers lake network coverage plan zone

Turin Use-Case

Technology Implementation

- The initial deployment will use 5G NSA (Non-Standalone) technology.
- WindTre plans to implement 5G SA (Standalone) in H1 2025.

Microwave backhauling link

The microwave link will connect the new BTS to the WindTre Core Network. Below are the key technical details:

Table 2. Microwave backhauling link specification

Component	Specification
Frequency	18 GHz
Antenna size	30-60 cm, dual-polarized
Channel spacing	112 MHz
Configuration	4+0 XPIC
Theoretical capacity	Up to 4 Gbps

A coverage simulation (Figure 9) compared the current and expected coverage levels after the new BTS installation.

- Turquoise – represents the minimum 5G signal level required to provide service outdoors at a typical mobile user ground level. This is the current coverage level in most of the area.
- Red – represents a 15 dB signal gain compared to the turquoise level.
- Expected Impact: after installing the new BTS, simulations indicate that the red-level coverage will significantly extend in the relevant area.

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Figure 9. Simulation of the coverage level by installing the new BTS in Turin.

It is important to note that the simulation tool is designed to provide coverage predictions at ground level (typically assumed to be 1.5 meters above the ground), similar to standard mobile network simulations. It does not account for coverage at flying altitudes.

At higher altitudes, signals from multiple BTS can be received, leading to increased interference levels. However, deploying a dedicated BTS near the hill's summit, combined with the beamforming capabilities of new active antennas, is expected to enhance the Signal-to-Interference-plus-Noise Ratio (SINR) and improve overall performance even at elevated heights.

The figure below presents the initial default parameter settings for the BTS activation. Once the BTS is operational, each parameter will be further optimised based on direct on-field measurements.

Table 3. Initial default configuration data will be used for the BTS activation.

Dati di Sito	
Dati Scheda	
Tipo Scheda	ARPA_NO_WIND
Data Redazione	2025-02-03
Redattore	[redacted]
Dati Generali	
Nome Sito	Area volo Progetto 5G4Lives - Torino
Codice Sito	XA780
Candidato	A
Localizzazione	
Comune	PIE - TO - TORINO - 001272
Indirizzo	Presso Cremaliera superga
Lat(WGS84)	45°04'53.4"
Long(WGS84)	07°45'58.3"
Y(Gauss-Boaga)	0.00
X(Gauss-Boaga)	0.00
Varie	
Progetto	5G
Struttura	Carrato
Note	Carrello provvisorio per Area volo Progetto 5G4Lives - Torino
Antenne Sito	4

Dati di Cella										
Num Settore	1	1	1	1	1	2	2	2	2	2
Banda	LTE1800	LTE2100	LTE2600	5GN38	5GN78	LTE1800	LTE2100	LTE2600	5GN38	5GN78
Num.Ramo	0	0	0	0	0	0	0	0	0	0
Dati Generali Bts										
Tipo Alloggiamento	Room	Room	Room	Room	Room	Room	Room	Room	Room	Room
Tipo Rbs	ERI_6150	ERI_6150	ERI_6150	ERI_6150	ERI_6150	ERI_6150	ERI_6150	ERI_6150	ERI_6150	ERI_6150
Numero Portanti Totale	1	1	1	1	1	1	1	1	1	1
Tipo CDU/RU	ERI_4466	ERI_4466	ERI_4466	no_CDU	no_CDU	ERI_4466	ERI_4466	ERI_4466	no_CDU	no_CDU
Note Cella	4T4R	-	4T4R	-	-	4T4R	-	4T4R	-	-
Tma/Cavi										
Utilizzo TMA/ASC/SBT	FALSO	FALSO	FALSO	FALSO	FALSO	FALSO	FALSO	FALSO	FALSO	FALSO
Tipo TMA/ASC/SBT	-	-	-	-	-	-	-	-	-	-
Posizione TMA/ASC/SBT	-	-	-	-	-	-	-	-	-	-
Diplexer	NO_DIPLEXER	NO_DIPLEXER	NO_DIPLEXER	NO_DIPLEXER	NO_DIPLEXER	NO_DIPLEXER	NO_DIPLEXER	NO_DIPLEXER	NO_DIPLEXER	NO_DIPLEXER
Lunghezza Cavi(m)	18.00	18.00	18.00	0.00	0.00	18.00	18.00	18.00	0.00	0.00
Diametro Cavi(")	1/2	1/2	1/2	-	-	1/2	1/2	1/2	-	-
Sistema d'Antenna										
N.Antenne	1	Multi-Band	Multi-Band	1	Multi-Band	1	Multi-Band	Multi-Band	1	Multi-Band
H.B.A. Tetto(m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H.B.A. Suolo(m)	18.12	18.12	18.12	16.78	16.78	18.12	18.12	18.12	16.78	16.78
H.C.E. Tetto(m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H.C.E. Suolo(m)	18.60	18.60	18.60	17.20	17.20	18.60	18.60	18.60	17.20	17.20
Azimuth(°)	240	240	240	240	240	320	320	320	320	320
Azimuth_Radio(°)	240	240	240	240	240	320	320	320	320	320
Posizione Antenna	-	-	-	-	-	-	-	-	-	-
Costr. Antenna	CellMax	CellMax	CellMax	Ericsson	Ericsson	CellMax	CellMax	CellMax	Ericsson	Ericsson
Modello Antenna	CMA-UBDHH/6518/E2-10	CMA-UBDHH/6518/E2-10	CMA-UBDHH/6518/E2-10	AIR3228_M2D	AIR3228_M2D	CMA-UBDHH/6518/E2-10	CMA-UBDHH/6518/E2-10	CMA-UBDHH/6518/E2-10	AIR3228_M2D	AIR3228_M2D
Guadagno(dBi)	17.50	17.90	18.50	21.50	24.20	17.50	17.90	18.50	21.50	24.20
Polarizzazione	XXPol	XXPol	XXPol	XPol	XPol	XXPol	XXPol	XXPol	XPol	XPol
Altezza(mm)	950.0	950.0	950.0	841.0	841.0	950.0	950.0	950.0	841.0	841.0
Larghezza(mm)	284.0	284.0	284.0	524.0	524.0	284.0	284.0	284.0	524.0	524.0
Profondità(mm)	135.0	135.0	135.0	222.0	222.0	135.0	135.0	135.0	222.0	222.0
Lobo 3dB Orizz.(°)	66.0	62.0	55.0	65.0	65.0	66.0	62.0	55.0	65.0	65.0
Lobo 3dB Vert.(°)	9.8	8.8	7.0	13.0	10.0	9.8	8.8	7.0	13.0	10.0
Range Tilt Elettrico	2 - 10	2 - 10	2 - 10	-2 - 5	-2 - 5	2 - 10	2 - 10	2 - 10	-2 - 5	-2 - 5
Tipo Downtilt Elettrico	RET_I	RET_I	RET_I	RET_I	RET_I	RET_I	RET_I	RET_I	RET_I	RET_I
Config.Connettori	-	-	-	-	-	-	-	-	-	-
Downtilt Elettrico(°)	8	8	8	2	2	8	8	8	2	2
Tilt El SubArray(°)	8	8	8	2	2	8	8	8	2	2
Downtilt Meccanico(°)	0	0	0	4	4	0	0	0	4	4
Separazione Antenne(m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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Dati di Cella										
Num Settore	1	1	1	1	1	2	2	2	2	2
Banda	LTE1800	LTE2100	LTE2600	5GN38	5GN78	LTE1800	LTE2100	LTE2600	5GN38	5GN78
Num.Ramo	0	0	0	0	0	0	0	0	0	0
Potenze										
Pot.Cpich/PRS/SSB(dBm)	10.40	15.20	8.20	12.20	17.20	15.20	15.20	12.20	12.20	17.20
Pot.Max(dBm)	52.00	52.00	52.00	46.00	50.00	52.00	52.00	52.00	46.00	50.00
Atten. Sw(dB)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potenza Impostata(dBm)	52.00	52.00	52.00	46.00	50.00	52.00	52.00	52.00	46.00	50.00
Perdita CDU(dB)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potenza Uscita da Bts(dBm)	52.00	52.00	52.00	46.00	50.00	52.00	52.00	52.00	46.00	50.00
Perdita Diplexer(dB)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perdite Cavi(dB)	1.82	1.98	2.27	0.00	0.00	1.82	1.98	2.27	0.00	0.00
Altre Perdite(dB)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potenza all'Antenna(dBm)	50.18	50.02	49.73	46.00	50.00	50.18	50.02	49.73	46.00	50.00
Eirp(dBm)	67.68	67.92	68.23	67.50	74.20	67.68	67.92	68.23	67.50	74.20
Tipo Copertura										
Copertura Outdoor	VERO	VERO	VERO	VERO	VERO	VERO	VERO	VERO	VERO	VERO
Richiesta Configurazione										
N. Trx - 1a serie	1	1	1	1	1	1	1	1	1	1
Pot. per Trx all'Antenna(W) - 1a serie	104.50	100.50	94.00	40.00	100.00	104.50	100.50	94.00	40.00	100.00
N. Trx - 2a serie	0	0	0	0	0	0	0	0	0	0
Pot. per Trx all'Antenna(W) - 2a serie	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potenza Totale all'Antenna(W)	104.50	100.50	94.00	40.00	100.00	104.50	100.50	94.00	40.00	100.00
Eirp(dBm)	67.69	67.92	68.23	67.52	74.20	67.69	67.92	68.23	67.52	74.20
Eirp Totale Settore(dBm)	77.05	77.05	77.05	77.05	77.05	77.05	77.05	77.05	77.05	77.05
Pot. Tot Antenna - DTX_PC(W)	-	-	-	-	-	-	-	-	-	-
Eirp-DTX_PC(dBm)	-	-	-	-	-	-	-	-	-	-
Eirp Tot Settore - DTX_PC(dBm)	-	-	-	-	-	-	-	-	-	-
Tilt Elettrico Richiesto(°)	8	8	8	2	2	8	8	8	2	2
Tilt Meccanico Richiesto(°)	0	0	0	4	4	0	0	0	4	4
MinTilt E. Rich.(°)	8	8	8	2	2	8	8	8	2	2
MaxTilt E. Rich.(°)	8	8	8	2	2	8	8	8	2	2
Min Tilt E SubArray(°)	8	8	8	2	2	8	8	8	2	2
Max Tilt E SubArray(°)	8	8	8	2	2	8	8	8	2	2
MinTilt M. Rich.(°)	0	0	0	4	4	0	0	0	4	4
MaxTilt M. Rich.(°)	0	0	0	4	4	0	0	0	4	4
Richiesta Configurazione - Fattori 5G										
K_TDD	-	-	-	0.750	0.750	-	-	-	0.750	0.750
K_PR	-	-	-	0.000	0.000	-	-	-	0.000	0.000
Actual Power(W)	-	-	-	30.00	75.00	-	-	-	30.00	75.00
Pwr_Lim_Esp(W)	-	-	-	30.00	75.00	-	-	-	30.00	75.00
Pwr_Val_Att(W)	-	-	-	30.00	75.00	-	-	-	30.00	75.00
Richiesta Configurazione - Dss										
DSS	VERO	FALSO	FALSO	FALSO	FALSO	VERO	FALSO	FALSO	FALSO	FALSO

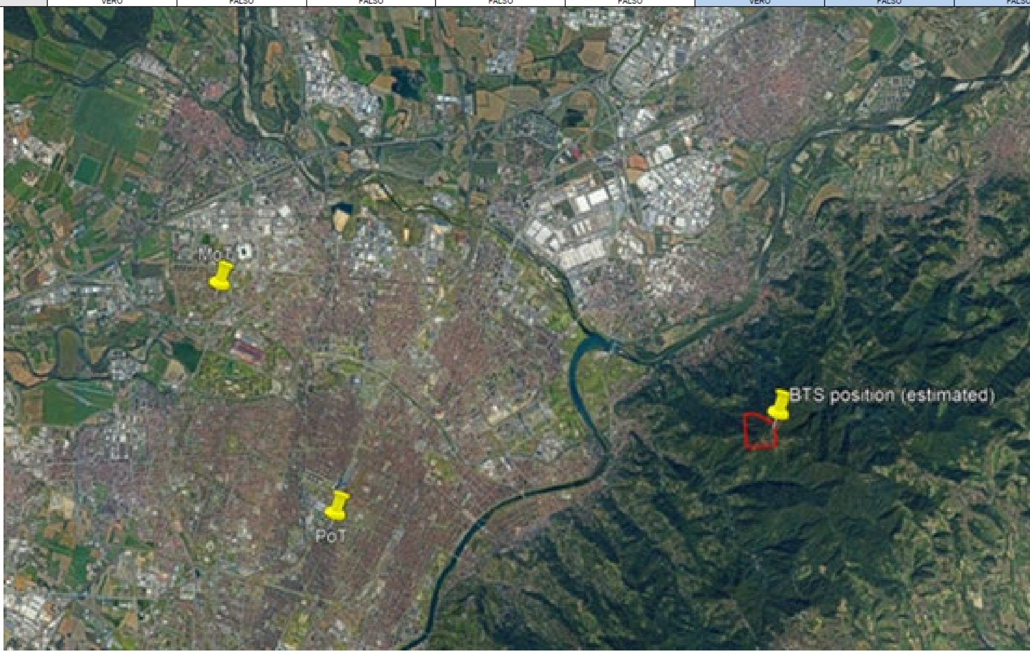

Figure 10. The position of the BTS, the flying test area (red polygon), the position of the MoT and PoT.

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Figure 11. The estimated position of the BTS, the azimuth of 2 sectors, and the flying test area (red polygon).

Details about MW BH link:

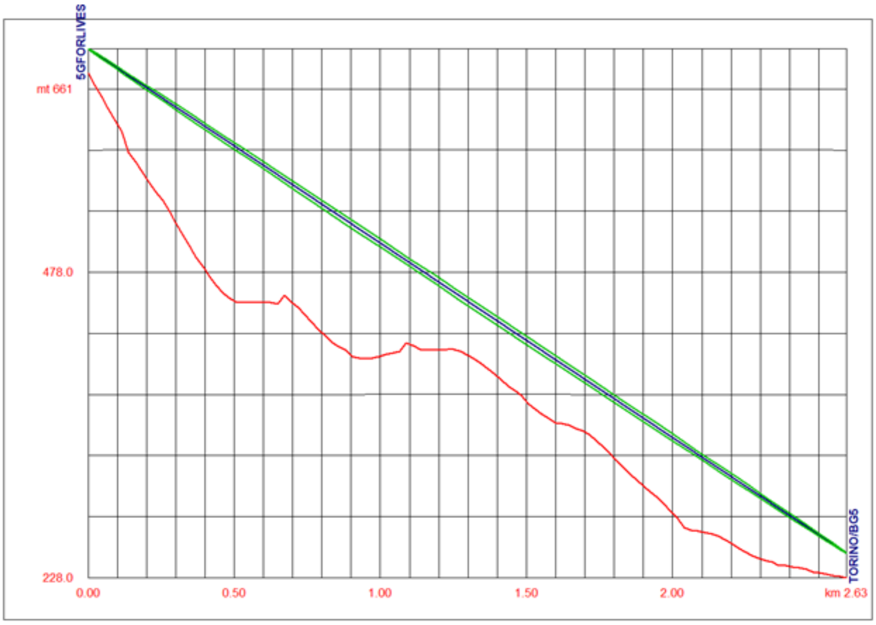

Figure 12. Altimetric profile of the MW radio link used for backhauling.

The tables below show the main parameters and link budget simulation of the MW link that will be used for the backhauling.

Table 4. Main parameters and link budget simulation of the MW link.

A SIDE	B SIDE
ID link: NO29411/1	Status: under study
Elevation:-009g03'00"44	Elevation: +009g01'36"48
frequency (GHz): 18	Channel width (MHz): 110.00
Polarisation: V	
channel TX (MHz): 18140.0000	channel TX (MHz):19150.0000
- Power Reference (dBm): 25.00	- Power Reference (dBm): 25.00

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- Modulation Min (Reference Mode): QPSK-STRONG	- Modulation Max: 2048QAM
- Bandwidth Min Configured (Reference Mode) (Mbit/s):154	- Bandwidth Max Configured (Mbit/s): 1047
type: N+0	type: N+0
- Diameter (cm):30.000	- Diameter (cm):60.000
- heigth (m): 20.0	- heigth (m): 20.0
Feeder 1: NESSUN FEEDER / 0.00 m	Feeder 1: NESSUN FEEDER / 0.00 m
Feeder 2: NESSUN FEEDER / 0.00 m	Feeder 2: NESSUN FEEDER / 0.00 m
Aggregation (4+0) with: NO29411/2 NO29411/3 NO29411/4	
Aggregation (CCDP) with: NO29411/2	

Table 5. Main parameters and link budget simulation of the MW link.

Parameter	A SIDE	B SIDE
Power in Tx (dBm)	25.00	25.00
Attenuation Tx (dB)	0.00	0.00
Global Attenuation feeder-splitter Tx (dB)	3.60	3.60
Branching Tx + Rx (dB)	0.00	0.00
Antenna gain Tx (dBi)	33.80	39.00
Additional Attenuation (dB)	0.00	0.00
link's attenuation – simulation model (dB) [Free-Space]	125.97	126.44
Attenuation from gas in atmosphere (dB)	0.26	0.35
link's attenuation - Other (dB)	0.00	0.00
Attenuation ground reflection (dB)	0.00	0.00
Attenuation passive repeater (dB)	0.00	0.00
Antenna gain Rx (dBi)	39.00	33.80
Attenuation Rx (dB)	0.00	0.00
Global attenuation feeder-splitter Rx (dB)	3.60	3.60
Total link gain (dB)	97.80	97.80
Total link attenuation (dB)	133.43	133.99
Received power th (no att. gas)(dBm)	-35.37	-35.84
Received power (dBm)	-35.63	-36.19
Threshold power in Rx (dBm)	-83.50	-83.50
Theoretical margin (dB)	47.87	47.31
Threshold C / I in Rx (dB)	12.00	12.00
Interfering power (dBm)	-	-121.70
Real margin (dB)	47.87	47.31

NOTE: The table values come from a radio link's link budget simulation. The effective executive project for this link will be generated when the definitive position of the BTS is confirmed.

To deploy a new base station for the Wind Tre network, the standard procedure is as follows:

1. The opinions of the municipality and region where the site is to be created are requested
2. Where needed, the Operator asks for the necessary municipal/regional authorisation and also requests an opinion about the following topics:
    - Landscape.
    - Hydrogeological risks.
    - Wooded areas.
    - Park.
    - Fine arts etc.

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3. CIL (communication of the start of civil works) is registered
4. The works are carried out
5. There will be a RSU (Structure Completed Report) + Testing (civil engineering)
6. The site goes "on air"
7. CFL (communication of the end of civil works) + CAI (activation system)

Once the opinions that insist on that area have been obtained through the maps (all design/architecture studios have them), the Operator can start with the implementation by nominating a Works Management Director, a tester, according to the project submitted to the municipality.

From a preparation point of view, to have the BTS ready for the test, Wind Tre is waiting for the authorities' answer to obtain the permit to occupy public ground near the test area. After that, the procedure for commissioning a BTS, as described in more detail in the previous section, will be started, with more activities done in parallel – when possible – to save time. The BTS will be put on air using a standard configuration as shown in the previous section, too, to be aligned with the Wind Tre RF Planning guideline, further optimisation will be put in place after preliminary tests to guarantee the best coverage and performance level.

1.4. 5G NETWORK ASSESSMENT

Integrating UAV systems into 5G infrastructure is an innovative component, and many steps in this process are not yet fully standardised. One of the key aspects is the verification and assessment of the deployed mobile network to determine critical network performance indicators, the operation of user equipment, and other essential parameters. To ensure the seamless integration of drones into the network, ECO has developed the 5G4LIVES network assessment methodology (See Figure 1), enabling evaluation and providing recommendations for deploying mobile networks with integrated drones. It's crucial to mention that the methodology requires further improvements and refinements to ensure its applicability across various use cases. While ECO has conducted multiple practical measurements during the project's lifespan using drones, additional test flights across different environments and conditions are necessary to validate the methodology further, ensuring it closely aligns with real-world applications.

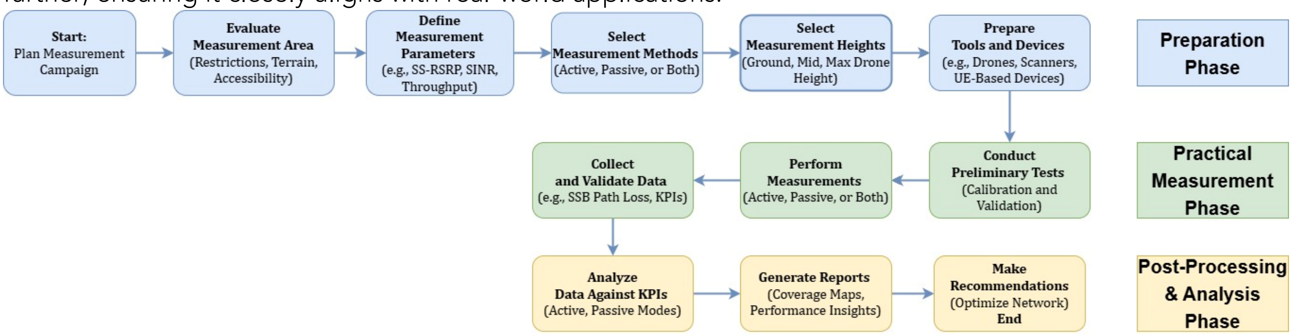

Figure 13. 5G Network assessment methodology for drone-based measurements (Flowchart).

The 5G network assessment methodology developed by ECO is structured into three main phases, which may vary depending on specific conditions:

1. Preparation Phase.
2. Practical Measurement Phase.
3. Post-Processing & Analysis Phase.

The following sections provide a more detailed explanation of each phase, outlining its purpose and key aspects.

Preparation Phase

1. Start: plan measurement campaign

The first step is to understand the use case clearly, which defines the measurement campaign's specific needs, intended application, and expected outcomes. This includes identifying key performance indicators (KPIs) relevant to the use case, selecting suitable locations, and ensuring alignment with project goals. A well-defined use case helps determine the required measurement setup, data collection approach, and necessary resources while considering external factors such as time constraints and regulatory compliance.

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2. Evaluate measurement area (restrictions, terrain, accessibility)

A thorough assessment of the target measurement area is necessary to identify potential challenges. Restrictions such as airspace regulations, private property access, or interference zones must be considered. Additionally, terrain characteristics (e.g., urban density, elevation changes, or water bodies) and accessibility factors (such as road access for ground teams or flight permissions for drones) impact the campaign's feasibility.

3. Define measurement parameters (e.g., ss-rsrp, sinr, throughput)

The selection of appropriate measurement parameters is crucial for obtaining meaningful data and predicting potential problem areas. By defining the use case, we can determine which parameters, such as SS-RSRP (Reference Signal Received Power), SINR (Signal to Interference Noise Ratio), and Throughput (data rate performance) are most relevant for identifying coverage gaps and performance issues. Additional metrics, such as latency or handover efficiency, may be included based on the study's objectives, allowing for a more targeted analysis of network weaknesses and optimisation needs.

4. Select measurement methods (active, passive, or both)

Measurement methods must be chosen based on the use case or study requirements. Active measurements involve controlled network interactions, such as throughput tests that provide detailed insights but require network resources. On the other hand, passive measurements monitor real-world network behavior without generating traffic, making them ideal for observing network performance. Combining both methods can achieve a more comprehensive dataset, where active measurements provide detailed performance metrics. In contrast, passive measurements capture real-world network behavior without additional load on the system.

5. Select measurement heights (ground, mid, max drone height)

Measurement heights are selected to analyse network performance at different altitude levels. Ground-level measurements assess user experience in pedestrian or vehicular scenarios and network performance over water, which is crucial for low-flying UAVs conducting surveillance. Mid-range measurements provide insight into coverage for urban infrastructure and are also relevant for UAV applications operating at lower altitudes. Maximum drone height measurements help evaluate vertical coverage and signal propagation for UAV applications and aerial communication use cases.

6. Prepare tools and devices (e.g., drones, scanners, user equipment (UE)-based devices)

The final preparation step involves verifying and configuring all measurement equipment to ensure proper functionality. This includes checking drones for flight readiness and safety compliance, performing necessary firmware or software updates, and inspecting network scanners and user equipment for correct calibration. Cables and connections must be tested to prevent signal losses or malfunctions, while user equipment should be configured according to measurement requirements. Additionally, all drone-related operations must adhere to flight safety protocols, including battery checks, GPS calibration, and compliance with airspace regulations, to ensure safe and efficient data collection.

Practical measurement phase

Conduct preliminary tests. This step ensures that all necessary preparations are made before conducting drone-based measurements. It includes compliance with aviation regulations, requiring at least two people - a pilot to control the drone and a visual observer for safety. Additionally, one or two more staff members may be needed to operate and monitor the measurement equipment, ensuring accurate data collection. If real-time measurement data monitoring is impossible, verifying that the equipment is properly configured and receiving mobile network signals before the flight is crucial. After completing the flight, the recorded data must be reviewed to confirm successful measurements and ensure they meet the expected KPI values. This step minimises operational risks and enhances measurement quality.

Perform measurement. This step focuses on assessing 5G network performance by measuring KPIs such as SS-RSRP, SS-RSRQ, SS-SINR, throughput, and latency, which are essential for evaluating signal strength, quality, and reliability. It involves conducting real-world field measurements to capture network conditions and performance in various environments. Passive mode measurements are usually performed with dedicated equipment (scanners) that receive and decode all information transmitted by the base stations, such as network codes, cell IDs and certain configuration parameters. Active mode measurements are commonly referred to as network performance measurements, where the UE provides continuous data transmission over the 5G network, allowing the collection of coverage-related parameters (Downlink/ Uplink (DL/UL) and latency).

Collect and validate data. This step focuses on systematically storing, organising, and verifying measurement data to ensure accuracy and reliability for further analysis. All collected data should be stored in a structured format (e.g., CSV, SQL database) to enable efficient access and processing. Dedicated software typically provides functionality for post-processing measurement files, allowing data to be extracted into various formats, ensuring flexibility and compatibility with different analysis tools. It is crucial to verify that all relevant KPIs, such as signal strength, quality, and network performance metrics, are captured at every measurement point to maintain data integrity and reliability for subsequent evaluation.

Post-Processing & Analysis Phase

1. Analyse data against KPI.

This phase is conducted after the measurements have been completed to evaluate the performance of the radio components of a 5G base station using key metrics, such as Coverage Availability Parameters and Network Performance Parameters. The analysis verifies that the network adheres to defined KPIs and aligns with 5G standards and the specific requirements defined for the use case. The process consists of several key steps:

- Data Preprocessing – cleaning and organising raw measurement data.
- Data Normalization and Aggregation –standardising data to ensure consistency and comparability.
- Data Analysis for Passive and Active Measurements – evaluating both scanner-based and UE-based measurements to assess signal strength, coverage, and overall network performance.

These steps help to ensure the correct interpretation of data, identify potential gaps in signal coverage and quality, and provide valuable insights for optimising network performance.

2. Generate reports

Reporting and visualisation are essential for presenting 5G network performance results from drone-based measurements. This step focuses on processing and structuring the validated measurement data, removing inaccurate or erroneous results. The goal is to create clear, insightful visualisations that communicate the findings, particularly the expected network performance based on the defined use case requirements.

By creating visual representations, such as heatmaps and route overlays, test performers unfamiliar with the measurement process in the measurement process can easily interpret the results. These visualisations provide a comprehensive overview of network coverage, highlighting areas that meet expectations and those requiring further optimisation. Presenting complex data in an accessible format ensures that key insights are effectively communicated, supporting informed decision-making for network improvements.

3. Recommendations for Optimization

To realise the full potential of 5G technology and meet user expectations, mobile network operators need to prioritise performance optimisation at every stage of network deployment and operation. Detection of network coverage gaps in areas where signal parameters are below the thresholds, the main tasks to improve coverage should be implemented.

Through a systematic combination of infrastructure upgrades, repeated measurements and dynamic monitoring, the network can maintain optimal performance and reliability over time, meeting the changing demands of all use-case scenarios. It is important to note that acceptable thresholds for KPIs such as throughput, delay and packet loss rate can vary significantly depending on the use case. These thresholds are influenced by the number of devices, data traffic requirements (e.g. video signal transmission) and network configuration. Accurate measurements of these parameters are therefore essential to confirm the ability of the network to support the intended applications without disruption. This section briefly overviews the 5G network assessment methodology and its development process. The methodology has already been documented and will be further refined and included in other project deliverables. Each methodology section has been described in detail or will be further elaborated as the work progresses. In developing this approach, we have conducted extensive research, including reviewing various recommendations, standards, and regulations related to drones, mobile network measurement techniques, and signal evaluation parameters. Additionally, we have collaborated with mobile network operators to define appropriate threshold values that align with real-world network conditions, ensuring the methodology's applicability across different scenarios.

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Furthermore, this methodology will be compiled into a formal report and submitted to the Electronic Communications Committee (ECC) working group. We will discuss with communications administrations to encourage similar measurement efforts across European countries. These discussions will help determine whether this methodology should be formally adopted and contribute to developing European recommendations, promoting a standardised approach for 5G network assessments using drone-based measurements.

1.5. NETWORK CYBERSECURITY

Cybersecurity and Data Protection Measures at Wind Tre.

A part for the embedded security features already provided by the 5G 3GPP standard, inside WindTre technological investments have already been made and others are planned to face cyber-threats as telecommunications service providers continue to play an essential role, since they represent the gateway to the web for families and businesses. This responsibility requires a great deal of attention, both in terms of innovation, with the adoption of increasingly advanced and secure technologies and infrastructures, and in terms of knowledge, through the continuous and rigorous internal personnel training.

Our commitment:

- Investing in a cybersecurity infrastructure to protect the data of customers
- Offering services designed to help corporate customers to handle the digital evolution of their businesses safely
- Preventing possible loss or damage of the data managed, and limiting the damage and restoring normal business operations as quickly as possible if any incidents do occur
- Implementing the latest regulations and maintaining a constant dialogue with the authorities to establish and update the best privacy protection standards in the field of telecommunications
- Disseminating a Cybersecurity Mindset throughout the company to prevent human error.

Cyber-attacks have increased exponentially in data exchanged between companies and users interacting with digital infrastructures. Cybersecurity is at the center of the debate between companies and regulatory authorities. It has led to establishing a regulatory framework for ensuring national security and the resilience of critical infrastructures. Wind Tre's collaboration with the institutional bodies responsible for cybersecurity started years ago, as did the internal activities of reviewing the data and information security management framework and developing processes and technical solutions to protect customer and Wind Tre data.

Wind Tre's direct investments in services and platforms for data and system security focused on the following main lines of development:

- Network security – Wind Tre has combined its platform distribution activities with a structured testing plan (vulnerability assessments/penetration tests) to bolster security measures
- Service continuity – Wind Tre has defined a structured disaster recovery process that leverages the resilience capabilities of the network and IT systems to ensure optimum service continuity
- Customer solutions – The technologies, skills and processes developed by Wind Tre for the protection of its own business are being exploited to offer solutions and services capable of helping client companies securely handle the digital evolution of their businesses
- Cloud Transition—Business processes are increasingly using cloud technologies. To facilitate the transition to these technologies and provide its customers with the highest cybersecurity services, Wind Tre has decided to renovate its security infrastructure, focusing on the design, implementation, and monitoring processes.

Throughout the year, CyberIntelligence has played an essential role in protecting the Wind Tre service infrastructure and preventing cyber threats, even by monitoring the alarm bulletins issued by national and international institutions. The Security Operations Centre (SOC) plays the main role in this area. This Wind Tre operations centre uses various monitoring and control systems to continuously prevent and neutralise threats in real time, using advanced data analysis and process automation technologies.

In 2023, Wind Tre continued to bolster its risk prevention and mitigation processes by implementing Security by Design principles. This means, wherever possible, providing security criteria appropriate to the

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company's exposure level and customer data right from the initial requirement definition stages. These same principles are implemented throughout the supply chain, where specific security checklists verify that the suppliers have also adopted specific data protection measures.

Digitalisation has led to an increase in the number of cyber-attacks suffered by companies. However, the so-called H factor (Human Factor) is one of the main causes of security incidents and remains a major cybersecurity weakness for most companies. That’s why it is important to disseminate a Cybersecurity Mindset throughout the company. This can be done by acting on two levels: awareness, which leads people to become more aware of their behavior, and learning, to encourage the acquisition of new knowledge and the adoption of virtuous behaviors, to mitigate cyber threats and the inherent dangers associated with technology.

By paying attention to changes to national cybersecurity regulations and interacting with the competent authorities, Wind Tre constantly adapts its processes to implement increasingly effective measures for preventing and responding to cybersecurity attacks in full compliance with the said regulations. For this reason, Wind Tre also invests in strategic cyberthreat intelligence activities, which allow the teams involved in various capacities at the company to focus on the potential risks and anticipate them by identifying potential threats and possible countermeasures. The topics of privacy and data security are extremely important to Wind Tre, which, as a telecommunications operator, manages an enormous amount of personal information regarding its customers. Wind Tre is not only responsible for the customer data that it manages directly, but also for all the information deriving from the business relationships that the company has with third parties who manage part of the commercial and service processes and who, consequently, need to process customer data in full regulatory legitimacy as data controllers. The company has taken all the measures necessary to ensure data security and compliance with the latest privacy and cybersecurity legislation in its and its customers' interests. About both the Italian and European legislative contexts, the company’s policy on privacy and data security is primarily aimed at ensuring regulatory compliance, taking into account the introduction of the General Data Protection Regulation (GDPR), approved in 2016 and effective since 2018, of the Privacy Code as amended by Legislative Decree 101/2018 as well as the Provisions issued by the Privacy Authority, including the introduction of new cookie guidelines, after which Wind Tre updated its cookie policy. Thanks to the harmonisation processes conducted in recent years, Wind Tre has now implemented a Governance, Risk Management and Compliance (eGRC) system, which allows it to monitor data processing throughout the entire supply chain. Specific monitoring activities are periodically conducted with all the company managers to maintain the Log of Processing activities. This is complemented by a verification activity, which is carried out through a self-assessment system for all appointed data processors, using an electronic dashboard to quickly disseminate and process the self-assessment questionnaires sent out to all of Wind Tre’s partners through specific ‘Self Assessment’ campaigns. The company maintains a fully cooperative relationship with the GPDP (Personal Data Protection Authority) to determine the best privacy protection standards for the telecommunications sector. Within its responsibilities as Data Controller, Wind Tre has increased the supervision of its External Data Processors by enacting strict procedures and thorough processes, to guarantee total governance of the data under its control. Supervisory activities on site resulted in the sending to the affected Partners a report containing the non-conformities found during the activities and the remediations to be adopted to comply with current privacy legislation and the instructions given by Wind Tre. Customer reports, including those received by the Authority, are also regularly answered.

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CONCLUSIONS

The presented technical solutions constitute the complete 5G network design for integration into the 5G4LIVES concept for both operational locations. Certain modifications to the initial technical specifications were identified and implemented compared to the initial concepts and assumptions developed in Deliverables D2.1 and D2.2. Specifically, network frequency and specification details were refined for the Riga Use-Case to ensure optimal performance and future scalability.

The 5G4LIVES partner LMT will utilise the n78 band to support the Riga Use-Case, deploying both Standalone (SA) and Non-Standalone (NSA) modes. The 5G network will function independently in SA mode, offering full 5G benefits, such as ultra-low latency and high data throughput. In NSA mode, 5G will operate alongside the existing 4G infrastructure, ensuring a seamless transition while delivering partial 5G advantages. Initially, network slicing will not be implemented. This technology, which segments the network into virtual partitions optimised for different use cases (e.g., UAV control, video transmission), may be introduced later in LMT's infrastructure. If implemented, network slicing will enhance UAV operations by prioritising critical communications, ensuring reliable resource allocation for safety-critical signals.

For deploying the solution, existing LMT infrastructure will be leveraged, with modifications planned for six base stations across operational sites. Enhancements will include the installation of new antennas and adjustments to existing components to meet the specific requirements of 5G4LIVES.

In Turin Use-Case, partner Wind Tre chose to deploy a dedicated 5G base station on the hillside demonstration area – a van-mounted cell site with dual-sector antennas oriented roughly at 250° and 330° – to provide targeted coverage for the use-case scenario. This movable BTS transmits both LTE (1800/2100/2600 MHz) and 5G NR (n38, n78) signals, creating a local high-speed network for emergency communications. A microwave backhaul link was selected to connect the mobile cell to the core network, as it offers protected, high-capacity connectivity that can be rapidly deployed in remote areas (faster and more cost-effectively than laying fiber). The 5G system implementation uses advanced radio features to maximise performance. In Turin's case, the base station supports 4T4R MIMO and Massive MIMO on its active antennas, improving throughput and signal quality for drone uplink/downlink. Low-frequency bands (for greater range and penetration) and mid-bands (for capacity) balance coverage and bandwidth needs. Quality of Service (quality of service) mechanisms are in place to prioritise mission-critical UAV communications, leveraging 5G's ability to provide ultra-reliable low-latency connections. Network security considerations have been incorporated to ensure the secure connection of users and the protection of transmitted data. The approach focuses on reliability, resilience, and vulnerability mitigation, ensuring that the 5G network infrastructure meets the security requirements for UAV operations and emergency response scenarios.

The 5G Network Assessment Methodology has been proposed and structured to evaluate network performance for UAV operations and connectivity. It includes a detailed workflow and steps to ensure reliable and efficient integration of 5G networks for UAV applications. The assessment methodology focuses on key performance indicators such as latency, throughput, network coverage, and reliability to support BVLOS operations, real-time data transmission, and mission-critical UAV tasks.

The structured approach ensures a systematic evaluation process, covering different operational scenarios, network conditions, and environmental constraints. This methodology allows stakeholders to optimise UAV connectivity, address network bottlenecks, and ensure compliance with regulatory and operational requirements.

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2. UAV INTEGRATION

The 5G4LIVES UAV Integration focuses on selecting and incorporating advanced drones into emergency response operations, optimised to the specific scenarios in Turin and Riga. This section details the drone platforms chosen for each use case and justifies their selection with technical specifications and operational requirements. The focus is ensuring that UAVs meet safety and regulatory standards for extended-range flights, including European drone classification and BVLOS capabilities criteria. The drones are capable of high-endurance flights and real-time HD video transmission. Still, they are also connected via 5G networks to enable reliable remote control and data upload during missions. The section provides a comprehensive overview of technical specifications, including software, drone operations, maintenance infrastructure, and components, and describes performance characteristics, such as flight endurance, payload sensors, and communication systems. Additionally, this section describes the supporting infrastructure – including any UAV docking/charging stations and ground control systems – and how these components interact to automate drone operations. Technical and regulatory considerations (like UAV certification classes, Remote ID compliance, and standard scenario adherence) are outlined to show that the drones are fully prepared for real-world lifeguard and disaster-response missions.

2.1. Torino Use-Case UAV solution

2.1.1. UAV Platform

As previously anticipated, use cases 1 and 2 will be conducted using two drones. Specifically, use case 1 will be conducted with a DJI Matrice M30T, while use case 2 will be conducted with an AgEagle Ebee X. Each drone platform is detailed below.

Use Case 1. DJI Matrice M30T

The DJI Matrice M30T is a high-performance professional drone with an approximately 40 minutes flight endurance capable of capturing and transmitting high-definition videos. The M30T drone has several characteristics that make the drone suitable for performing BVLOS flights in safe conditions:

- *Safe and reliable*: Dual-vision and ToF sensors enable 360° vision of the aircraft to detect and avoid obstacles, keeping it and your mission safe. The built-in ADS-B receiver provides timely warnings of any incoming crewed aircraft nearby. The aircraft provides a three-propeller emergency landing.
- *Able to fly in critical and harvesting environments*: The M30T can fly in windy conditions with a wind speed up to 12 m/s, has IP55 protection, and can fly in an environment with a temperature ranging between -20° and 50°.
- *Provide Redundancy systems* for flight control sensors (dual IMU, dual barometer, dual GNSS module, dual compass, several obstacle detection/avoidance sensors), for control signal, dual batteries, dual transmission links. These features make the aircraft suitable for conducting safe flight missions.
- *C2 (EU) classification:* the aircraft meets the requirements imposed by EASA for the C2 (EU) identification label class.

The features previously described allow the M30T to be suitable for conducting the flight operation of the use case 1. The safety and reliability of the aircraft with a C2 (EU) class are essential for conducting a safe flight even in critical scenarios. Moreover, the M30T aircraft meets some of the requirements imposed by EASA to perform critical operations, such as:

- Redundancy systems (dual GNSS, dual IMU, etc.)
- Failsafe procedures: automatic Return to home (RTH), emergency landing, ability to enable geofencing
- Support of the Remote ID function
- Detect and Avoid system
- Long range communication, even with the 4G Cellular network
- Compatible with some Flight Termination Systems (FTS) EASA-compliance on the market

Some other specifications are listed in Table X.

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Table 6. DJI Matrice M30T drone specification.

Specification	Value
Dimension (excluding propellers)	470×585×215 mm (L×W×H)
Weight (including two batteries)	3770 ± 10 g
Max Takeoff Weight	4069 g (limited to 3998 g for the C2 EU Certification)
Operation Frequency	2.4000-2.4835 GHz; 5.725-5.850 GHz
Max Ascent/Descent Speed	6 m/s, 5 m/s
Max Horizontal Speed	23 m/s
Max Wind Resistance	12 m/s
Max Hover Time	36 min
Max Flight Time	41 min
Ingress Protection Rating	IP55
Operating Temperature	-20° to 50° C

One of the criteria for choosing this drone is the possibility of equipping it with a mobile connection module. Only the 4G Cellular Dongle is available on the EU market to enable a 4G connection between the drone and the ground segment (remote controller or other connected platforms). However, 5G modules will be released on the EU market soon, but the timing is unknown. Some devices have already been released on the Asian market but cannot be purchased.

Figure 14. DJI Matrice M30T.

Use Case 2. AgEagle eBee X

The eBee X is a fixed-wing drone designed for large coverage and mapping with a long endurance of up to 90 minutes flight. This drone was selected to perform use case 2, where the goal was to provide a monitoring task for risk assessment. The eBee X drone is a suitable aircraft for conducting safe BVLOS flights: in fact, it is one of the few drones on the market with the C6 (EU) certification. This certification enables using this drone within the STS-02 Standard Scenario, i.e., a BVLOS flight over a controlled ground area. According to the EASA requirements, the eBee X drone implements the following features:

- The aircraft was subjected to the M2 Mitigation Design Verification for the SORA process from EASA. This verification process makes the drone suitable to fly over people
- Implementation of fail-safe protocols, also considering the live air traffic
- Equipped with an EASA-compliance Remote ID
- Possibility to set geofences to delimit the flight area
- Automatic safe return when the battery is low or signal loss

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General specifications are listed in Table X.

Table 7. AgEagle eBee X drone specification

Specification	Value
Wingspan	1.16 m
Weight (incl. camera & battery)	1.3 kg - 1.6 kg, depending on camera and battery
Radio link range	3 km nominal (up to 8 km)
Cruise speed	11 to 30 m/s
Wind resistance	Up to 12.8 m/s
Maximum flight time	Up to 90 minutes, depending on camera and battery

Even if the drone has a limited payload (a typical characteristic of fixed-wing aircraft), it can be equipped with several sensors for monitoring applications, such as photogrammetry, multispectral, and thermal cameras.

Figure 15. AgEagle eBee X.

2.1.2. Payload and sensors

In the case of the use-case 1 in Turin, a DJI Matrice 30T drone will be used with the following payload:

Table 8. DJI Matrice 30T payload and sensors specification.

Component	Specifications
Zoom Camera	- Sensor: CMOS 1/2"; effective pixels: 48 MP - Focal length: 21-75 mm (equivalent: 113-405 mm) - Aperture: f/2.8-f/4.2 - Focus: 5 m to ∞
Wide-Angle Camera	- Sensor: CMOS 1/2"; effective pixels: 12 MP - DFOV: 84° - Focal length: 4.5 mm (equivalent: 24 mm) - Aperture: f/2.8 - Focus: 1 m to ∞
Thermal Camera	- Thermal Imager: Uncooled VOx microbolometer - DFOV: 61° - Focal length: 9.1 mm (equivalent: 40 mm) - Aperture: f/1.0 - Focus: 5 m to ∞
Thermal Camera Parameters	- Noise Equivalent Temperature Difference (NETD): ≤50 mk at F1.0 - Infrared Temperature Measurement Accuracy: ±2°C or ±2% (whichever is higher)
FPV Camera	- Resolution: 1920×1080 - DFOV: 161° - Frame Rate: 30 fps

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Laser Module	- Wavelength: 905 nm - Maximum Laser Power: 3.5 mW - Single Pulse Width: 6 ns - Measurement Accuracy: ± (0.2 m + D×0.15%) - Measurement Range: 3-1,200 m (vertical surfaces 0.5 x 12 m with 20% reflectivity) - Safety Regulation Level: Class 1M - Accessible Emission Limit (AEL): 304.8 nJ - Reference Aperture: Length: 18 mm, Width: 18 mm (diameter of 20.3 mm if circular equivalent) - Maximum Pulse Laser Emission Power within 5 Nanoseconds: 60.96 W
Vision Systems	- Obstacle Detection Distance: Front: 0.6-38 m Top/Bottom/Rear/Side: 0.5-33 m - FOV: 65° (H), 50° (V) - Operating Environment: Textured surfaces with adequate lighting (>15 lux)
Infrared Sensing Systems	- Obstacle Detection Distance: 0.1 to 10 m - FOV: 30° - Operating Environment: Large obstacles with diffuse reflection (reflectivity >10%)

Within use-case 2 in Turin, a SenseFly eBee X drone will be used with the payload S.O.D.A. 3D. The Solution is optimised for 3D reconstruction; its wide field of view ensures excellent 3D mapping results in vertically focused environments. Georeferencing of the images is performed directly in flight, recording the GPS position and the exact orientation of S.O.D.A. 3D in each capture position.

Table 9. SenseFly eBee X payload and sensors specification.

Specification	Details
Sensor	1"
RGB Lens	F/2.8-11, 10.6 mm (35 mm equivalent: 29 mm)
RGB Resolution	5,472 x 3,648 px (3:2)
RGB Shutter	Global Shutter 1/30 – 1/2000s
White Balance	Auto, sunny, cloudy, shady
ISO Range	125-6400
RGB Field of View (FOV)	Total FOV: 154°, 64° optical, 90° mechanical
Support RTK/PPK	Yes

2.1.3. Command, Control, Communications links

The DJI Matrice M30T and the AgEagle eBee X drones come with the manufacturer's Remote Controller and GCS (Ground Control Station), which offer advanced planning, mission management, and other features: the following details each GCS, remote controller, and communication link.

Use Case 1. DJI Matrice M30T

The M30T drone can be controlled via a DJI RC Plus remote controller for enterprise users. This controller has a 7-inch screen and supports the Dual operator mode, enhancing the system's safety and redundancy.

The controller adopts four antennas with the DJI OcuSync 3 Enterprise communication. The communication link adopts an operation frequency at 2.4 GHz and 5.8 GHz with an operational range up to 8 km, while ensuring a safe communication up to 1.5 km even in urban areas with strong interferences. Moreover, the Remote Controller can be equipped with a 4G Cellular Dongle to enable access to the Internet and, then, also enable communication with the drone over the 4G network.

In the following table, some details about the Remote Controller are reported:

Table 10. DJI Matrice M30T remote controller specification.

Remote Controller Specification	Value

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Screen	7.02-inch LCD touchscreen, with a resolution of 1920×1200 pixels
Ingress Protection Rating	IP54
Operating Temperature	-20° to 50° C
O3 Enterprise Communication Link Specification	Value
Operating Frequency	2.4000-2.4835 GHz, 5.725-5.850 GHz
Max Transmission Distance (unobstructed, free of interference)	8 km
Max Transmission Distance (with interference)	Strong Interference (urban landscape, limited line of sight, many competing signals): 1.5-3 km Medium Interference (suburban landscape, open line of sight, some competing signals): 3-6 km Weak Interference (open landscape abundant line of sight, few competing signals): 6-8 km

Figure 16. DJI Matrice M30T remote controller

The remote controller is equipped with the DJI Pilot 2 software that includes an interface designed to improve the piloting efficiency and flight safety. The DJI Pilot 2 software can manually control the aircraft, payload, and plan and execute automatic flights. The software is also compatible with BVLOS flight missions, enabling the real-time video streaming of the navigation camera and the drone's telemetry. Some additional safety features include pre-flight checklists that help UAS operators and the adoption of alert notifications that enhance situation awareness.

Use Case 2. AgEagle eBee X

The AgEagle eBee drone can be controlled and managed using a Ground Control Station based on the eMotion software. Unlike a traditional quadcopter, the eBee X drone cannot be controlled using a traditional Remote Controller. However, the eMotion software implements all the required features to conduct an automatic BVLOS flight, such as mission planning, mission management, and visualisation of real-time telemetry data. Moreover, it allows the flight mission to be simulated before taking off.

The eMotion software has been designed to enable the BVLOS flight. Some essential functionalities for BVLOS are:

- Interaction during the drone flight: update the flight path and control the drone during the flight execution
- Airspace management: import geo-awareness maps to have all the restricted and no-fly zones on the flight map
- Notifications and warnings: audio and color-coded notifications before and during flight

Moreover, in case of critical issues such as low battery, communication link degradation, GNSS degradation and strong wind, some safety actions can be defined, such as emergency landing or return home.

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A USB ground modem using the 2.4 GHz frequency links the eBee X drone and the Ground Control Station. It has a maximum range of 8 km and a nominal range of 3 km.

2.1.4. Software and operation functionality

The ground control station and the remote controller were described in the previous sections. These systems, however, are primarily intended for the Pilot in Command (PIC), who must supervise the flight mission and take control of the drone in case of emergency.

In the use cases addressed by the 5G4LIVES project, a remotely accessible platform is necessary for planning, carrying out, and supervising the flight mission. In particular, the Turin use case aims to use a platform accessible from the Protezione Civile control room that is usable for planning automatic missions, performing BVLOS missions, and supervising flight operations. For this specific functionality, we adopted the DROMThub platform provided by DROMT.

The solution provided by the DROMT company with its platform called DromtHUB was identified for this purpose and adopted for the first time by the Drones Unit of the City of Turin.

2.1.5. Technical Description of the DROMThub Platform

DROMT is an innovative startup specialising in software development for the drone industry. Its mission is to establish itself as the Italian ecosystem for the drone world and make its use simpler and more accessible. To achieve this goal, DROMT has developed the DROMThub platform.

DROMThub is a platform for pilots, operators, flight schools, and professionals. It offers the necessary digital tools to operate and provide services in the drone sector.

The digital tools available on DROMThub are divided into the following sections:

1. Dashboard
2. Pilot
3. Flight
4. Analysis

The following subsections provide a detailed description of the functionalities related to each section.

Dashboard description

The Dashboard section of DROMThub provides a clear and intuitive visualisation of d-flight geo-zones, the regulated geographic areas for drone flights. This information is crucial for pilots, operators, and professionals in the sector, as it displays flight restrictions based on the current regulations set by ENAC (Italian Civil Aviation Authority).

The d-flight geo-zones are divided into two main categories:

- Open Category: low-risk operations that do not require specific authorisations.
- Specific Category: operations that require an Operational Authorization, a specific authorisation issued by ENAC based on an operational risk assessment.

The Dashboard offers an interactive map that displays real-time restrictions and applicable regulations for each flight area. Pilots can plan their operations by verifying flight compatibility with current regulations. Additionally, the platform provides tools to support the Operation Authorization request in the Specific Category, allowing operators to consult applicable regulations and initiate the authorisation process directly from the platform.

DROMThub ensures safe operations through an automated verification system that cross-checks pilot and operator information with regulatory requirements. This validation process helps prevent violations and enhances operational safety. The Dashboard section also integrates real-time data on weather conditions and other environmental factors that could impact flights, enabling users to make informed decisions about mission feasibility.

The Dashboard aims to facilitate regulatory compliance by providing an updated overview of flight regulations. It aims to improve operational safety by cross-checking pilot and operator information and streamlining the authorisation process by assisting users in requesting the necessary approvals. Thanks to these features, the DROMThub Dashboard is essential for managing drone operations, ensuring efficiency and safety for all industry professionals.

Profile description

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The Operator/Pilot section of DROMThub is designed as a comprehensive management tool that allows users to handle all their documentation and personal information efficiently. Through this section, each operator or pilot can create and update their digital profile, keeping flight documentation and regulatory paperwork organised to ensure compliance with current regulations.

This feature enables users to register and store their flight certifications, drone insurance, and other relevant documents for operational activities. It also allows for the storage and management of personal information, flight account details, qualifications, equipment used, and operational availability. The platform provides an intuitive interface, allowing quick access to documents anytime, ensuring a more efficient and secure workflow. By offering this profile management tool, DROMThub is an essential resource for drone operators and pilots, providing a centralised environment for managing certifications and required documentation. The integration with other platform features ensures a complete and well-structured experience, simplifying bureaucracy and enhancing operational efficiency.

Flight description

The Flight section of DROMThub integrates advanced technology from the DROMTfly application, which is designed to ensure compatibility with most commercial drones. Available for devices and remote controllers running Android 8.0.0 or higher, this application provides advanced tools for mission planning and execution. Users can plan automated flight missions through this section to intuitively map areas and facades. The flight plan is automatically generated based on user-defined parameters, ensuring precision and operational efficiency. During the mission execution, if an internet connection is available, DROMThub offers a multi-device Live Streaming feature, allowing multiple users to monitor the flight in real-time.

DROMThub also supports BVLOS (Beyond Visual Line of Sight) flights, enabling remote drone control from an operations center. This functionality is essential for advanced operations, such as large-scale inspections, environmental monitoring, and missions in complex environments. In addition to these features, DROMThub provides detailed mission reports. After each flight, the system automatically generates a comprehensive report containing key data, including the flight path, captured images, operational conditions, and detected anomalies. This tool is crucial for analysing operations, improving performance, and ensuring regulatory compliance.

With these integrated features, the Flight section of DROMThub helps optimise operations, enhance safety, and expand operational possibilities for pilots and operators, delivering a professional and technologically advanced flight experience.

Analysis description

Once the mission is completed, DROMThub provides proprietary software tools for analysing and processing images collected during the flight. One of the main tools available is the aerial photogrammetry processing software, which enables the detailed and precise terrain reconstruction using drone-captured images.

This software allows users to generate various types of cartographic outputs, including:

- Orthophotos: high-resolution, georeferenced images that provide a detailed terrain view, commonly used for topographic surveys and environmental monitoring.
- DTM (Digital Terrain Model): digital models of the terrain that represent land morphology while removing surface elements such as buildings and vegetation.
- DSM (Digital Surface Model): digital models of the surface that include structures and elements above the ground, useful for urban planning and spatial analysis.
- 3D Models: three-dimensional representations of terrain or specific structures, widely used in architecture, cultural heritage management, and security applications.

These analyses have primary use cases in environmental monitoring, precision agriculture, infrastructure management, urban planning, and geological risk prevention. Through DROMThub's integrated tools, users can process, visualise, and download these outputs efficiently, optimising their operations and enhancing the quality of acquired data.

Solution technical summary

DROMThub is a cloud-based platform capable of exchanging messages (commands, metrics, media, etc.) in real-time between two clients:

1. The first client is connected to the drone and executes the actions.

2. The second client generates the commands to be performed.

For example, when used with DJI drones—which hold approximately 70% of the commercial drone market share and are among the brands compatible with DROMThub—the system operates as follows:

- An Android application interfaces with the drone and must be installed on the smartphone connected to the remote controller.
- This application, using SDKs provided by the manufacturer, allows direct control of the drone.
- On the other end, a web app generates commands and controls while receiving real-time feedback from the controlled drone.

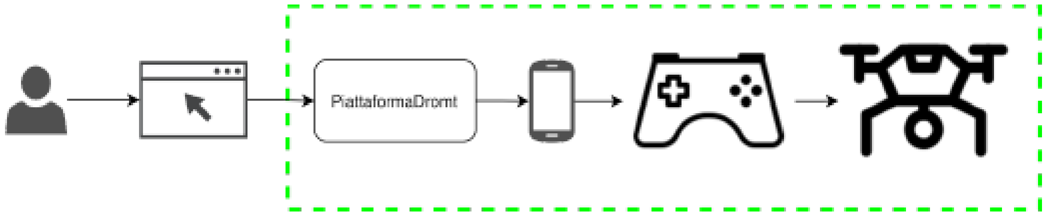

Figure 17. DROMThub solution infrastructure chart.

Client requirements description

The example infrastructure is illustrated in the previous figure. The DROMThub platform's operating perimeter is outlined in green. Those interfacing with the platform must create a new client (as shown on the left side of the figure) that uses the APIs exposed by the platform. The service is available over HTTPS and requires client authentication through TLS, using a certificate signed and issued by DROMT. Once connected to the server and having implemented the protocol using RPC, it is possible to:

- Use individual calls and connections for each command to be sent.
- alternatively, open a single "stream" session to transmit all necessary commands.

In this second mode, receiving all metrics and logs generated by the drone in response to the commands is possible.

2.1.6. Cybersecurity

Dromt Platform description for the Civil Protection of Turin

The Dromt platform is a data management system for drone-collected information. It utilises advanced technologies to offer innovative services to its clients.

Compliance

For Dromt, data and workload security are top priorities. For this reason, two outstanding and highly efficient hosting partners have been carefully selected to ensure that all data and workloads are stored in secure hosting environments that comply with international regulations and the most stringent best practices. Our primary hosting partner is Amazon Web Services (AWS), a global cloud computing and storage services leader. AWS holds numerous certifications, including the prestigious ISO 27001, which guarantees the highest level of security and compliance with international standards. Thanks to AWS, Dromt benefits from scalable infrastructure, advanced security measures, and high availability of data and workloads.

In addition to AWS, Dromt utilises Hetzner's services to host certain workloads. Hetzner is a renowned cloud and dedicated hosting service provider, certified with ISO 27001, demonstrating its commitment to maintaining the highest information security standards. By storing data and workloads on AWS and Hetzner, Dromt ensures a diversified distribution of resources across multiple locations within the European Union, thereby reducing the risk of a single point of failure.

Both hosting partners, AWS and Hetzner, are ISO 27001 certified, an internationally recognised standard for information security management. The ISO 27001 certification confirms that an organisation has implemented an Information Security Management System (ISMS) that meets stringent requirements. This certification entails a systematic and proactive approach to managing information security risks. ISO 27001-certified entities must identify potential vulnerabilities and threats, assess risks, and implement appropriate mitigation control measures.

Compliance with ISO 27001 ensures rigorous procedures are in place to protect the confidentiality, integrity, and availability of information. This includes, but is not limited to, data access policies, encryption,

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security incident management, staff training, and business continuity planning. For Dromt, partnering with ISO 27001-certified providers like AWS and Hetzner guarantees that data and workloads are handled according to the highest security standards and fully compliant with international regulations. This minimises the risk of breaches and ensures the secure and reliable management of critical information.

GDPR

Dromt is committed to ensuring that its data processing and storage practices fully comply with the General Data Protection Regulation (GDPR), which took effect on May 25, 2018. The GDPR is a regulatory framework established by the European Union to harmonise privacy laws across Europe, protect the personal data of all EU citizens, and reform how organisations across the continent handle data protection.

In line with European regulations, Dromt recognises the importance of safeguarding individuals' data and understands the serious consequences of non-compliance, which may include significant financial penalties and reputational damage. Therefore, the company has implemented strict policies and procedures to ensure personal data is processed fairly, transparently, and securely. Specifically, Dromt has developed a highly detailed data protection program that includes data encryption, data minimisation, pseudonymisation, and anonymisation, as well as robust security measures such as encryption, access controls, and regular data backups.

Furthermore, Dromt ensures transparency and accountability throughout the process by maintaining detailed records of processing activities and making them available to the relevant authorities upon request. Under certain circumstances, data subjects can access their data, request corrections or deletions, and object to processing. Dromt is committed to responding to such requests promptly and fully complying with GDPR provisions. In conclusion, strict adherence to the GDPR protects users' data and strengthens customer and business partner trust, reinforcing Dromt’s reputation as a responsible and reliable company.

Vulnerability and threat analysis

The Dromt platform has been thoroughly analysed to identify, assess, and mitigate/minimise potential vulnerabilities and threats that could compromise data security and integrity. Some of the identified risk areas include:

- Software vulnerabilities: the platform relies on various software and frameworks for operation. Dromt ensures these software components are constantly updated and secured to prevent data breaches.
- External threats: the platform is exposed to cyberattacks and network intrusions. Dromt ensures the platform is configured to maximise resilience against such threats by implementing advanced security measures to protect data.
- Internal threats: the platform may be subject to internal threats, such as implementation errors or improper permission management. The platform's design and implementation have been carried out with security as the top priority.
- Data leakage: Since the platform collects and processes sensitive data, measures have been taken to prevent and ensure data protection.

To mitigate these threats and vulnerabilities, a security plan has been implemented, which includes:

- Credential and authorisation management: credentials are kept current and secure to prevent unauthorised access to user data.
- Microservices configuration: microservices are configured to ensure data protection and withstand network threats.
- Continuous monitoring: the platform is constantly monitored to detect and address potential issues before they cause harm.
- Advanced security measures: Advanced security measures, such as data encryption in transit and API call management, have been implemented.

Dromt will continue to monitor the platform to identify new vulnerabilities and threats and implement additional security measures to protect user data.

Credential management and authorisation

Keycloak, a widely used open-source software in industrial environments, operates as an OIDC Identity Provider for credentials management and authorisation. Keycloak is recognised for its robustness and reliability in ensuring user data security and controlling access to services. It offers a wide range of advanced security features, including:

- Two-Factor Authentication (2FA): To enhance security, Keycloak supports two-factor authentication, which requires users to provide a second form of verification in addition to their password.
- Single Sign-On (SSO): this feature allows users to access multiple applications with a single authentication, reducing the risk of phishing and improving the user experience.
- Identity and Access Management (IAM): Keycloak facilitates centralised management of user identities and their access permissions, ensuring that only authorised users can access sensitive data and resources.
- Standardized Security Protocols: Keycloak supports industry-standard security protocols such as OpenID Connect, OAuth 2.0, and SAML 2.0, ensuring the integrity and confidentiality of communications.
- Protection Against Common Attacks: the system includes protective mechanisms against common attacks such as brute force, phishing, and cross-site scripting (XSS), further strengthening security.

In addition to these features, Keycloak is configured to ensure access is granted exclusively to employees approved by the organisation or specifically authorised users. This strict level of control significantly reduces the risk of unauthorised access.

Keycloak, with its solid reputation and advanced capabilities, provides a high level of security for Dromt's identity and access management operations. Additionally, Dromt employs unified access via Google for all accounts, allowing users to authenticate using Google Workspace or Google accounts with two-factor authentication. Google sessions are protected by multiple two-factor authentication mechanisms, including access codes and security keys, ensuring that access is restricted to legitimate users only. The adoption of Keycloak and its integration with Google for two-factor authentication demonstrates Dromt's commitment to implementing best security practices, ensuring a safe and protected environment for user data.

Communication flow security

The Dromt web platform is protected by an OIDC (OpenID Connect) authentication system, ensuring user data security and access control to services. Communication with the web platform is secured through HTTPS protocols, which encrypt data in transit, preventing interception and unauthorised access. Regarding the connection between drones and the server, mTLS (mutual Transport Layer Security) protocol is used. This protocol encrypts transmitted data and provides mutual authentication through digital certificates. This mechanism ensures that only authorised drones can access and securely communicate with the server, effectively minimising and eliminating the risk of intrusions from unauthorised devices.

Dromt's approach to communication flow protection integrates a combination of advanced technologies to ensure data security and integrity. From web platform access to drone-server communications, the implementation of OIDC for authentication, HTTPS for web encryption, and mTLS for drone-server security represents industry best practices for safeguarding sensitive information and maintaining a secure operational environment.

Configuration of authorisation policies and data access control

The Dromt platform is structured as a microservices-based system, where each microservice handles a specific functionality. Internal permission management relies on Role-Based Access Control (RBAC), which assigns users specific roles based on their responsibilities. These roles define access rights to data and functionalities, ensuring only authorised users can access certain information and perform specific operations. Traffic between microservices is encrypted using advanced security protocols, ensuring that data in transit is protected from interception and unauthorised modifications. This internal traffic encryption helps safeguard sensitive data and maintain the integrity of communications within the platform. The microservices' pods are based on Alpine Linux images, a lightweight and minimalistic operating system that reduces the potential attack surface. Additionally, all pods are configured with a read-only file system, preventing unauthorised modifications or tampering. This extra layer of protection ensures that the code and data within the pods remain intact and cannot be compromised.

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Dromt's approach to permission and authorisation management, with traffic encryption and the use of secure pod images, is designed to guarantee data security and integrity across the platform. These measures ensure compliance with the highest security standards.

Management of data collected by drones

Depending on the selected package, the Dromt platform allows organisations to delete or retain images based on their needs. In all cases, Dromt ensures that data is appropriately stored and adequately protected to prevent loss or damage.

Data management

The Dromt platform's data management system is based on an advanced security strategy that includes data encryption and triple replication to ensure durability and accessibility. Triple redundancy guarantees that if data is lost in one of the three copies, the information remains intact in the others. Additionally, having a third copy allows for verification and ensures data integrity. Critical information is stored in a PostgreSQL database, while multimedia content is securely hosted in Amazon S3. The entire workload and dataset reside in data centers within the European Union, certified according to DIN ISO/IEC 27001 standards (as detailed earlier in this document), ensuring the highest levels of security and compliance. Dromt carefully selects highly reliable service providers that adhere to strict security standards. PostgreSQL is widely recognised for its robustness and security in handling critical data, while Amazon S3 provides scalable and secure storage infrastructure with advanced access management and encryption capabilities.

In conclusion, the Dromt platform offers high data protection and is aligned with top international standards, thanks to a robust security strategy and collaboration with trusted service providers.

Physical access

Dromt places great importance on the physical security of data stored with AWS and Hetzner, whose security measures have been described in detail in previous sections of this document. Cloud service providers are responsible for the physical security of their hosting infrastructure, including servers, network devices, and storage units. AWS and Hetzner ensure that physical access to data centers is strictly limited to authorised personnel, who must obtain prior approval to access specific facilities.

Monitoring and alerting

Dromt's monitoring and alerting system is configured to detect incidents and promptly notify the responsible parties. This system constantly monitors the platform and identifies potential issues using performance indicators and security metrics.

- *Emergency plan (incident response plan)*
  The emergency plan includes constant communication with clients and employees, media management, and business recovery in an emergency. It is regularly implemented to ensure the maintenance of skills and knowledge within the organisation.
- *Security evaluation*
  The Dromt platform is highly rated in terms of security, thanks to the robust management of credentials and permissions, encryption of communication traffic, and strict configuration of authorisation and data access control policies. However, Dromt is constantly committed to improving and updating its security strategy to protect the platform.
- *Disclosure policy*
  Dromt follows the incident management and threat response process recommended by the SANS Institute, which includes the following phases: identification, containment, eradication, recovery, communication, and documentation of security events. In the rare event of a data breach, Dromt will promptly inform clients via email or phone.

2.2. Riga Use-Case UAV solution

2.2.1 UAV Platform

Deliverables 2.1 and 4.1 describe the operation scenarios, general requirements, and a detailed use case explanation. Based on these requirements, a detailed technical specification has been developed for all components of the drone solution, including UAVs, sensors, onboard equipment, ground infrastructure, and supporting software.

Below are the detailed requirements used for solution integration.

Table 11. UAV platform specification.

Requirements	Specification/description
SIZE	The diagonal size of the UAV (during flight, counting the propeller size) should not exceed 1 meter 15 cm.
MTOW	No more than 4000 grams (including power elements, propellers, etc., equipment)
UAV TYPE	Multirotor
FLYING TIME	At least 25 minutes non-stop UAV flight (without additional payload)
GLOBAL POSITIONING SYSTEM	Built-in global positioning system that supports GPS and supports at least two of the following systems: GLONASS, Galileo, BEIDOU. • Vertical accuracy: at least 0.5 m. • Horizontal accuracy: at least 1.5 m.
GEOFENCING	Geo-restriction feature that uses GPS technology to establish virtual geographical boundaries, within which drones can operate
NETWORK	The UAV must be equipped with a 4G/5G modem, that can support the following 3GPP bands: • n28: 703 MHz – 748 MHz / 758 MHz – 803 MHz; • n20: 832 MHz – 862 MHz / 791 MHz – 821 MHz; • n75: 1432 MHz – 1517 MHz; • n3: 1710 MHz – 1785 MHz / 1805 MHz – 1880 MHz; • n1: 1920MHz – 1980 MHz / 2110 MHz - 2170MHz; • n40: 2300 MHz – 2400MHz / 2300MHz – 2400 MHz; • n7: 2500 MHz – 2570 MHz / 2620 MHz – 2690 MHz; • n38: 2570 MHz – 2620 MHz / 2570 MHz – 2620 MHz; • n78: 3300 MHz – 3800 MHz, And can provide both control of the UAV and video streaming through the mobile network.
VIDEO STREAMING	ONVIF support has two video streams (FHD and thermal), encoding H.264.
OPERATION CONDITIONS	Intended for use in Latvian climatic conditions. Must be able to operate in temperatures from -10 C to +40 C. IP 44 or higher protection or signed confirmation from the executor.
WIND RESTRICTIONS	The feasibility of using UAS (Unmanned Aerial Systems) under wind conditions with speeds of up to 10 m/s.
OBSTACLE DETECTION SYSTEM	Equipped with at least a front-facing obstacle detection system with a range of at least 20 meters.
SPEAKER	The UAV is equipped with a built-in or connectable speaker (horn) capable of producing at least 100 dB at a distance of 1 meter.
IDENTIFICATION	Network remote ID
CERTIFICATION	CE certification

2.2.2. Docking station

The docking station is an integrated solution designed to support UAV operations. It is a centralised hub for UAVs, enabling automated takeoff, landing, charging, and data transfer (if required). Docking stations ensure operational efficiency, autonomy, and safety by reducing manual operations by the operation staff.

Docking stations can be fixed or mobile, depending on deployment needs. They can include automated charging/battery replacement mechanisms, weather-resistant enclosures, and remote monitoring capabilities.

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Table 12. Docking station specification.

Requirements	Specification/description
SIZE	The size of the docking station should not exceed 2x3 meters.
OPERATION AND CONDITIONS	• Must have an IP53 or higher protection rating. • Must be compatible with the offered UAV and capable of automatically charging or replacing the battery.
SENSORS	Temperature, wind speed and humidity.
NETWORK	The docking station must be connected to the internet or equipped with a 5G modem supporting the following bands: • n28: 703 MHz – 748 MHz / 758 MHz – 803 MHz; • n20: 832 MHz – 862 MHz / 791 MHz – 821 MHz; • n75: 1432 MHz – 1517 MHz; • n3: 1710 MHz – 1785 MHz / 1805 MHz – 1880 MHz; • n1 (1920MHz – 1980 MHz / 2110 MHz - 2170MHz); • n40 (2300 MHz – 2400MHz / 2300MHz – 2400 MHz) • n7: 2500 MHz – 2570 MHz / 2620 MHz – 2690 MHz; • n38: 2570 MHz – 2620 MHz / 2570 MHz – 2620 MHz; • n78: 3300 MHz – 3800 MHz.
FEEDING	AC 230V
RESERVE POWER SUPPLY	Must be able to ensure full operation of the docking station for at least 60 minutes

2.2.3. Payload and sensors

The requirements for payload capacity and sensors have been developed based on scenarios and specific Use Cases, considering different operational conditions (day/night) and cold and warm seasons. The requirements also considered integrating AI capabilities for object recognition during operations and the ability to georeference object information on the ground.

Table 13. UAV payload and sensors specification.

Requirements	Specification/description
SENSOR EFFECTIVE RESOLUTION	At least 12 MP with a CMOS sensor.
VIDEO RECORDING	4K: 3840×2160 at 30fps
THERMAL IMAGE SIZE	At least 640x480 at 30 fps
LENS	The digital zoom must be at least 10x for the standard lens and 2x for the thermal lens. The focal length should be no less than 13 mm and no more than 19 mm in full-frame equivalent. The lens must support 1080p video streaming for an RGB camera.
CAMERAS CONFIGURATION OPTIONS	Options to combine thermal and visual video in real-time. The video stream should display the GPS coordinates of the UAV and the camera angle.
OPERATION CONDITIONS	Aligned with the requirements of BGK-9.
CAMERA STABILIZER	A 3-axis camera stabiliser (gimbal) that ensures the oscillation of additional equipment (camera equipment) within a range of 90° (from the vertical reception axis to a positive angle for upward tilt).
LOCAL DATA STORAGE	Built-in memory with at least 50 GB by SD-Card insertion or any other method.

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2.2.4. Command, Control, Communications links

The requirements for control systems and C2 link have been developed considering the design and operational scenarios within the Remote-Operations Control Center environment, ensuring BVLOS operations and specific local regulatory requirements governing UAV flights.

Table 14. Command, control, C2 links specification.

Requirements	Specification/description
REMOTE CONTROL	The remote control must have two physical lever controls (joysticks). It should have 1 x HDMI and 1 x USB port (Type A or Type C). The USB port must support the connection to external data storage.
SCREEN	A built-in screen with a diagonal size of at least 5 inches and a brightness of at least 600 nits
BATTERY	Built-in battery capable of providing 3 hours of continuous operation at 15°C and 50% relative humidity.
SOFTWARE	Includes built-in, free of charge UAV management software.
REMOTE SOFTWARE CAPABILITIES	The software must support the following functionalities: • Manual (hand) control • Autopilot with automatic return to the departure point • Scheduled flight selection • Flight tracking on an external display device • Remote recording control • Live video streaming
LOCAL DATA STORAGE	Built-in memory with at least 32GB
CONTROL	The command and control (C2) connection signal delay—time between the remote pilot's command and the corresponding UAS execution—must not exceed 1 second.
MINIMUM REQUIREMENTS FOR C2 CONNECTION	• If a maneuver requires the transmission of multiple messages in a specific sequence, they must be sent such that execution occurs within a single uplink transmission. • Each message must be timestamped, indicating when the initiator commits the message for transmission. • The timestamp must represent the exact time the initiator generates the message for further processing. • All data processing steps (input, encoding, transmission, decoding, representation) must preserve the integrity and content of the original message. • The recipient system must automatically reject messages that are not addressed to it. • The initiating system must notify the end user if a response is not received within the specified time. • If a received message contains a timestamp indicating the time limit exceeded, the receiving system must automatically reject the message and notify the initiator or display an appropriate warning. • If the remote pilot is informed that a response was not sent within the specified time, a defined procedure must be in place to address the issue. • The recipient system must be capable of detecting corrupted messages. • A dynamic message prioritisation mechanism must be implemented to handle expired messages or messages received in a corrupted state effectively

2.2.5. Software and operation functionality

The software specification considers the ability to support UAV operations within the Remote Operation Control Center environment, enabling centralised management and execution of planned scenarios.

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The software provides direct control of drones in remote locations and fleet management components, including different access levels for personnel, digitisation of standard procedures, and ensuring reliable BVLOS operations.

Table 15. Operation software specification.

Requirements	Specification/description
ACCESS RIGHTS LEVELS	The software must support user authorisation with four levels of access rights. User roles should be defined during the user creation, ensuring access is restricted to the appropriate functions based on the assigned role.
ADMINISTRATOR	▪ Full access to all functions of the UAV, docking stations, and software. ▪ User management, including creating, deleting, and editing user accounts. ▪ Management of full flight plans, including creation, editing, and deletion. ▪ Monitoring and maintenance of the UAV, docking stations, and software.
CHIEF PILOT LEVEL	▪ Creation of new flight plans. ▪ Rescheduling or cancellation of existing flight plans. ▪ Forced termination of flights. ▪ Monitoring the condition of the UAV and related equipment.
PILOT LEVEL	▪ Execution of established flights. ▪ Forced termination of flights. ▪ Monitoring the condition of the UAV and related equipment.
THE OBSERVER LEVEL	▪ flight monitoring; ▪ UAV and equipment condition monitoring.
AUTHENTICATION	The software must provide secure login for users, utilising multi-factor authentication.
MAIN MENU	After logging in, the user is presented with a main screen featuring an OpenStreetMap layer or another map layer with higher detail. This screen provides access to all necessary functions for UAV management and monitoring.
INFORMATION SHOWN ON THE MAIN MENU	The Executor provides the software with the following functionalities (must have all of the below mentioned in any distribution/pathway): 1. **UAV control**: In this menu, the user can: 1.1. Select and control multiple UAVs. 1.2. Switch between different active UAVs. 1.3. Select previously created flight plans. 1.4. Create new flight plans. 1.5. Cancel flights. 2. **UAV and docking station status**: Displays the location and status of UAV and docking stations, including: 2.1. Charge levels. 2.2. Wind speed. 2.3. UAV and docking station IDs. 3. **Active flights or planned flight trajectories**: Viewable on the map interface. 4. **Information displayed during active flights**: 4.1. Distance between the docking station and UAV. 4.2. Battery charge level. 4.3. Remaining battery life. 4.4. Remaining time for the scheduled flight. 4.5. Current wind speed in m/s.

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	4.6. Current GNSS signal strength (categorised as strong, medium, or weak). 5. **Functions during active flights**: 5.1. Suspend UAV during a scheduled flight. 5.2. Replace the UAV at a specific location and take over the task (depending on battery charge level). 5.3. Start and stop video recording. 5.4. Capture photos. 5.5. Interrupt the scheduled flight. 5.6. Start a new scheduled flight. 5.7. Take direct control of the UAV. 6. **Online video streaming**: 6.1. Display online video before and during the flight. 6.2. Switch between thermal and standard video streams. 7. **Video image information**: 7.1. GPS coordinates of the UAV location. 7.2. UAV flying altitude. 7.3. Video camera direction and angle. 7.4. Zoom index. 7.5. Date and time of video recording.
WARNINGS	The software must provide the following warnings: ▪ Notification of the validity period of the user's access rights after logging in (displayed in red if the validity period is less than one month). ▪ UAV deviation from the planned flight route or altitude. ▪ Low battery level. ▪ Notification of upcoming UAV technical maintenance (parameters defined in UAV settings). ▪ Detection of a flying object approaching the UAV (at 500 m, 200 m, and 50 m in the horizontal and vertical planes). ▪ GPS signal interference. ▪ Video stream interruption. ▪ Obstacle detection system alerts. ▪ Inaccessibility of certain system equipment. ▪ Problems with the docking station, including power failure. ▪ Inability to land at the docking station. ▪ Activation of manual control mode (active until the UAV has landed at the docking station or a new scheduled flight has started)..
CREATING A NEW FLIGHT PLAN	The function can be displayed in the main menu. Its purpose is to create scheduled flights by configuring the following parameters: ▪ UAV flight route. ▪ Holding points. ▪ Flight height for each segment of the route. ▪ UAV replacement points to continue the flight. ▪ Flight speed for each stage of the flight. ▪ Camera direction and angle. ▪ Camera zoom index. ▪ The ability to manually perform and save a flight as a new scheduled flight. ▪ The option to import new scheduled flights.
FLIGHT LOG RECORDS	• Record the connection or disconnection from the software, including the event time, synchronised with Coordinated Universal Time (UTC).

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	• Record the Internet Protocol (IP) address from the operation. • Record the identifier of the initiator of each operation. • Log all operations performed in the system. System audit records must be created and stored for a minimum of 36 months after their creation. These records, or their copies, must be stored separately from the system to ensure their integrity.
OPERATIONS RECORDS JOURNAL	A dedicated section for browsing historical events and recording Emergency Response Plan (ERP) activation events. This section must store the following information: ▪ Information about UAV (manufacturer, model, serial number). ▪ Date, time, take-off, landing location, and flight route. ▪ Duration of each flight. ▪ Total flight hours and cycles. ▪ Remote pilot in charge of the flight. ▪ Actions taken during the flight. ▪ Significant incidents or accidents occurring during UAS operation. ▪ Information about ERP activation and actions taken, including: ▪ Completed ERP control card. ▪ ERP initial report form. ▪ Completed pre-flight inspection. ▪ Completed post-flight inspection. ▪ UAS defects and corrective actions taken. ▪ Details of any repairs or changes to the UAS configuration as a part of a separate logbook. ▪ Warnings received during the historical flight. Each new flight generates a separate record, ending when the flight is completed, terminated, or when a new manual or scheduled flight begins. **Data Selection Functionality:** The journal must include filtering options based on the following criteria: ▪ Date and time. ▪ Scheduled flight. ▪ Type of flight (scheduled or manual). ▪ Remote pilot in charge of the flight. ▪ ERP records. ▪ Flight time by remote pilot for a specified period.
CREATION OF USERS	The administrator manages user creation. The following user information must be recorded: ▪ **Username**: email address. ▪ **Password**: must be at least nine characters long and include: o At least one uppercase Latin letter. o At least one lowercase Latin letter. o At least one number or special symbol. ▪ **Name** and **Surname**. ▪ **Role**: user's assigned role and access rights. ▪ **Expiration Date**: the date when the user's rights will expire.
DIGITAL CHECK-LIST FUNCTIONALITY	The system must allow for the creation of checklists (checkpoint tables) and their completion at the appropriate stages of flight operations, such as: • Pre-flight checklist. • Post-flight checklist. • ERP incident checklist. **Pilot Features:**

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	The supplier must allow pilots to complete the control card by marking the fulfillment of each checkpoint during operations. Emergency Reporting (ERP): In an emergency, the system must support the initial completion of an ERP report. The software should automatically populate the following fields with available information: • Date and time of the incident. • Last recorded location of the UAV. • Remote pilot in charge. • UAV name and serial number. • UAV take-off mass. • Flight altitude when leaving the operating area (AGL). • Flight direction (skyward or relative to an identifiable object). • Estimated remaining flight duration. • Maximum flight speed. • Theoretical maximum flight distance. • Maximum possible flight altitude.
TYPE OF SOFTWARE	Suppose the software is not a web-based service or cannot be installed and used on a stationary device running the Windows operating system. In that case, the supplier must provide five units of computer equipment meeting or exceeding the following technical specifications: ▪ Screen dimensions: At least 24 inches. ▪ RAM: At least 8 GB. ▪ Storage: At least 512 GB SSD. ▪ Processor: no older than the last three generations of the current publicly available processor generation from the manufacturer.
SOFTWARE DEPLOYMENT	By prior agreement between the Parties, the Software shall be deployed on infrastructure managed by the Customer or the Supplier. Suppose the Software is deployed on the Customer's infrastructure. In that case, it shall be capable of running on VMware vSphere 7.x server virtualisation or Microsoft Azure cloud computing platforms using open source technologies where possible.
SOFTWARE LICENCES	Where licences are required to provide the necessary functionality of the software, the licences required to manage all the UAVs supplied, plus at least 30 user licences for the duration of the contract, shall be provided at no additional cost.

CONCLUSIONS

The Consortium identified and adopted UAV platforms that best fit the distinct mission requirements of its use cases, while ensuring compliance with aviation regulations for unmanned systems. In the Turin scenarios, two complementary drones were chosen: a DJI Matrice 30T quadcopter for Use Case 1 (providing real-time video surveillance of an emergency) and an AgEagle eBee X fixed-wing drone for Use Case 2 (performing broader area monitoring and risk assessment tasks). This dual-platform approach was a strategic decision – the Matrice 30T offers maneuverability and hover capability for close-up inspection and flying time up to 41 min., the eBee X covers large distances with long flight endurance (up to 90 minutes) for mapping and reconnaissance. For the Riga use-case (lifeguard operations at the beach and lake), the decision was made to utilise a multirotor drone integrated with a docking station. This implied selecting a UAV to automatically take off, land, and recharge, enabling persistent aerial patrols with reduced human intervention. The requirements specified a drone under 4 kg maximum takeoff weight, with at least 25 minutes of flight time per sortie, and equipped with cellular (5G) connectivity, ensuring the Remote Operations Control Centre concept.

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A major consideration in UAV integration was meeting European Union Aviation Safety Agency (EASA) regulations for advanced drone operations. The DJI Matrice 30T carries a C2 class marking under EU drone rules, indicating it meets requirements (like weight under 4 kg and necessary safety features) for moderate risk operations. The eBee X, notably, is one of the few drones with a C6 class certification, which specifically authorises its use in the STS-02 standard scenario (i.e. BVLOS flight over a controlled ground area). This certification was crucial: the fixed-wing eBee X can legally perform long-range missions in the project, as it passed rigorous design verification (including SORA M2 mitigation for operations over people). Both drones have Remote ID capabilities and geofencing functions to comply with airspace integration needs. The Matrice 30T's ability to use dual communication links (including 4G cellular by the docking station) ensures connectivity redundancy, which is aligned with EU requirements for command-and-control links in specific scenarios. Additionally, payload and sensor specs were defined. In the Turin Use-Case, a drone management software platform DROMT was integrated to oversee UAV operations within the 5G4LIVES system. This software acts as a mission control and UTM (Unmanned Traffic Management) interface. For the Riga Use-Case, very detailed technical specifications have been developed for the entire UAV solution, which ensures both the integration of the drone and all necessary components of the Remote-Operations Control Centre with the required level of automation. The automation of processes is also ensured by a dock station with the ability to charge/replace batteries; specifications for digital solutions for automating operator workflows have been described. The drone's flight time for the Riga Use-Case is at least 25 minutes, with an MTOW of no more than 4 kg. As sensors for observation and monitoring, a high-resolution camera of at least 12 MP with a CMOS sensor, capable of recording 4K video, will be used, as well as a thermal imaging sensor with a resolution of at least 640×480 (at 30 fps). Zoom capabilities include 10x zoom for the standard lens and 2x for the thermal lens.

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3. 5G4LIVES LIFEGUARD PLATFORM

Section outlines the integrated system architecture that combines 5G connectivity, UAV capabilities, and lifeguard services into a cohesive operational solution. It describes the principles of organising lifeguard operations powered by technology and details the general design of the platform that enables this advanced rescue system. In essence, this platform serves as an all-in-one command-and-control center: it allows for flight mission planning (including the option of fully automated drone missions under approved scenarios). It provides live video feeds to support situational awareness during emergencies. Section also presents how the platform is set up and functions within an operational lifeguard system. It covers the hardware and software components that form the lifeguard station, detailing how drones, control centers, and user interfaces are connected. The section also describes how this platform can be integrated into existing emergency response frameworks – ensuring that national, regional, and municipal authorities can interface with the system as needed.

3.1. Lifeguard station design, Turin Use-Case

The selected all-in-one platform enables flight mission planning and, if necessary, allows for fully automated execution (EU standard scenario STS-02). Additionally, its live streaming service provides real-time monitoring during drone flights, facilitating immediate operational supervision.

Following data collection in the field, the platform performs rapid data analysis and automatically processes the captured images, delivering quick and detailed insights to support decision-making.

3.1.1. Locations monitoring solution, Infrastructure and components integration

Civil protection scenarios are divided into three distinct levels:

- National Level
- Regional Level
- Municipal Level

At the national level, in cases of particular severity requiring the intervention of regional and national resources, the principle of subsidiarity applies, following the provisions outlined in the Prime Minister's Directive of December 3, 2008, titled "*Operational guidelines for emergency management.*" The Department of Civil Protection is responsible for drafting and coordinating the implementation of national plans related to specific national risk scenarios and national rescue programs. These programs outline the national organisational structure and provide the territorial knowledge necessary for operational response during national-level disasters.

Article 8 of the Civil Protection Code defines the national rescue programs as integrated with regional annexes and approved in agreement with the Department. These programs serve as national Civil Protection plans. Regions contribute to rescue and assistance activities for affected populations, including through the National Mobile Column of the Regions, coordinated either by the Operational Committee of Civil Protection or the Department of Civil Protection, with support from the Special Civil Protection Commission of the Conference of Regions and Autonomous Provinces.

Article 16 of the Code indicates that specific risk scenarios are considered in national planning. If such a scenario occurs, it can lead to an emergency requiring mobilisation and coordination of the entire National Civil Protection Service, per Article 7, paragraph 1, letter c of the Code.

The national plan describes the potentially affected territory and identifies the necessary measures to be implemented and the corresponding operational procedures to ensure population protection. In emergencies, drones can be used for search and rescue operations.

At the municipal level, the City of Turin is responsible for drafting municipal Civil Protection plans, following regional guidelines as outlined in Article 11, paragraph 1, letter b of the Civil Protection Code (D.Lgs 01/2018).

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Municipal Civil Protection planning must be proportional to the City of Turin's actual planning capacity. The plan must be developed, updated, and implemented by all municipal departments (e.g., urban planning, technical sectors, road infrastructure) under the coordination of the Municipal Civil Protection Service.

A key aspect is the technological development of drones – U.A.S. (Unmanned Aircraft Systems). Using aerial photogrammetry, drones can collect essential data on:

- The physical characteristics of the territory
- Anthropic settlements
- Infrastructure
- Natural and man-made risks

The territorial description must ensure consistency between different planning tools, and must be structured based on official planning documents, which include:

- Administrative and demographic framework
- Orographic, meteorological, and hydrographic framework, specifying, for example, the hydrographic basin of the Turin hills and its corresponding management unit, including the identification of buildings and infrastructure

By leveraging 5G drone technology, it is possible to plan and configure key elements for emergency management, such as:

- Infrastructure and essential services networks, including roads, railways, electricity, gas, water, and telecommunications
- Landfills, waste recovery plants, and storage facilities
- Urban and environmental planning tools, such as landscape, urban planning, and flood risk management plans

These plans, particularly for the Turin Hills, can be enhanced through drone-based photogrammetric techniques.

According to Article 2, paragraph 2 of the Code, identifying and studying hazard and risk scenarios is a forecasting activity supporting early warning and Civil Protection planning.

The Civil Protection Code defines this forecasting activity as dynamic and evolving, improving through drones and Artificial Intelligence (AI). With 5G technology, AI can be applied to:

- Recognize and detect emergencies
- Adapt Civil Protection response strategies in real-time
- Enable probabilistic forecasting and remote monitoring

These considerations apply to all territorial levels, from municipal to national. The primary goal of any risk scenario within a Civil Protection plan is to guide decision-making and ensure the implementation of strategic actions, such as:

- Identification of operational centers and emergency areas
- Application of 5G and drone technologies

A risk scenario integrates:

1. Descriptive analysis, supported by vector and raster cartography, obtained through drone-based aerial photogrammetry with multi-sensor payloads
2. Evaluative analysis, assessing the impact on people, property, settlements, animals, and the environment

Risk scenarios follow predefined probability models based on historical events, such as those referenced in D.Lgs. 23/02/2010, n. 49 – "*Implementation of Directive 2007/60/EC on assessing and managing flood risks.*"

In addition to statistical and probabilistic considerations, direct testimonies and real-time territorial monitoring provide critical insights for risk assessment.

In some cases, achieving a level of detail and informational richness compatible solely with higher-level thematic cartography is impossible. For this reason, the City of Turin utilises drones to enhance thematic mapping, achieving greater detail and higher quality.

Through this improved observation, it is possible to identify critical points or areas, such as:

- Underpasses, topographically depressed zones, or areas with poor drainage (for hydraulic risk)
- Embankment sections with territorial criticalities

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It is essential to develop an " event scenario " for hydrogeological, hydraulic, and adverse meteorological risks and to enhance early warning actions.

The event scenario must describe the phenomena that may occur in the examined area, defining:

- Their intensity
- The affected areas
- The expected paths of development
- Trigger points
- Other essential characteristics

For hydraulic risk assessment, reference should be made primarily to areas classified as hazardous in:

- Hydrogeological Structure Plans (PAI)
- Flood Risk Management Plans (PGRA), prepared by district basin authorities

Particular attention should be given to high-risk areas defined by lower return periods (20–50 years). These correspond to the highest criticality level in the hydrogeological and hydraulic risk warning system.

This approach serves as a preliminary scenario for planning, which must then be expanded to include higher magnitude but less frequent scenarios corresponding to longer return periods, as defined in the PAI/PGRA.

Regarding hydraulic risk, hazard maps in the PAI/PGRA may be insufficient because:

1. They mainly consider primary and partially secondary water networks
2. They do not account for local flooding caused by inadequate urban drainage systems
3. They assume the perfect functionality of hydraulic infrastructures and do not consider the effects of embankment failures. In such cases, potential hydraulic and hydrogeological risk areas can be identified using:

- Historical event records
- Studies on potential local flood and overflow mechanisms available to the relevant authority.

3.2. Remote Operation Control Centre

3.2.1. Operations principles

Civil Protection Planning outlines the organisation and operation of the structure at the relevant territorial level—regional, provincial/metropolitan city, district, and municipal—responsible for Civil Protection functions. It specifies the central and peripheral offices and coordination centers managed by the territorial authority in charge of planning.

The Civil Protection Authorities, as defined in Article 3, Paragraph 1 of the Civil Protection Code, ensure the engagement of all administration offices/departments during ordinary times and emergencies, maximising participation in Civil Protection activities. The Civil Protection structure must also coordinate its activities with external entities and administrations.

Each territorial level must establish an organisational framework that enables the activation of an intervention model in an emergency. This Civil Protection structure must include:

- Properly trained personnel in Civil Protection activities
- Certified BVLOS pilots for aerial photogrammetry surveys

The strategic and operational elements of Civil Protection planning define the organisational aspects and physical components needed to apply the intervention model. Unless otherwise specified, the elements listed below are general and apply to all territorial levels (regional, provincial/metropolitan city, district, and municipal).

The Civil Protection Plan may also identify strategies tailored to local needs and specify the organisations, agencies, or support functions responsible for their implementation.

Early warning system and communication flow

The Civil Protection Plan, concerning predictable risks, defines alert procedures through a structured communication flow, compliant with national and regional directives. The responsibilities of each component within the National Early Warning System remain unchanged, as outlined in Article 28 of Decree-Law No. 32 of April 18, 2019, converted into Law No. 55 of June 14, 2019, including the use of mass communication systems.

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The Department of Civil Protection has implemented a public alarm system called "IT-Alert", whose organisation and operation are regulated by:

- Article 15 of the Civil Protection Code (Legislative Decree 01/2018)
- Directive of the Prime Minister (October 23, 2020)
- Subsequent operational guidelines issued by the Head of the Department of Civil Protection

The early warning system applies to predictable events, with probabilistic forecasting and pre-announcement alerts, activating various levels of Civil Protection coordination.

Once alert messages are issued, operational response phases are activated at different territorial levels, as defined by their respective Civil Protection Plans, to counter and manage the event.

The Civil Protection Plan also identifies the officials responsible for receiving alert messages and the actions to be taken during different operational phases.

At the municipal level, the Civil Protection Plan defines the procedures through which the municipality receives and reviews alerts:

- Criticality bulletins/warnings and any other documents required within the regional early warning system for predictable events, such as floods, landslides, adverse meteorological events, volcanic activity, wildfires, and tsunamis.
- Information flow with coordination bodies, including the Region, the Prefecture – Territorial Government Office, and the Province/Metropolitan City, as well as with operational components and structures in the territory. These include:
    - The National Fire Brigade Corps
    - The Armed Forces
    - The Police Forces
    - Organized Civil Protection volunteer groups
    - The Italian Red Cross Association
    - The National Alpine and Speleological Rescue Corps
    - Healthcare and hospital organisations
    - Neighboring municipalities within the same jurisdiction, for exchanging information on critical situations.

Early warning system communications are transmitted from the Regions to the Municipalities to facilitate territorial monitoring by local municipal units.

Coordination Centers are key strategic elements in Civil Protection planning for emergency management. They ensure the accurate monitoring of the situation and the availability of resources. Each Administration/Territorial Entity's Civil Protection Plan must include the location and organisation of its coordination center, structured into support functions, as well as any peripheral operational centers affiliated with it.

The organisational structure at different coordination levels is activated progressively in the event of a predictable emergency, which aligns with specific operational phases. The support functions, which correspond to specific sectors for emergency management, are defined as follows:

- Coordination unit
- Representation of operational structures
- Population assistance
- Health and social assistance
- Logistics
- Emergency telecommunications
- Accessibility and mobility
- Essential services
- Drone aerial operations
- Technical and evaluation
- Damage assessment and structural integrity
- Volunteering
- Cultural heritage representation
- Press and communication

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- Administrative and financial support
- Administrative continuity

These functions are outlined in the Civil Protection Plan based on the expected activities and can be merged, reduced, or expanded depending on the availability of trained personnel. Each function has a designated point of contact. In a predictable emergency, the Coordination Center is activated in the configuration established by the Civil Protection Plan, either modular or progressive, depending on how the event unfolds. The plan specifies contacts and support function members within the organisational structure (without naming individuals but indicating their roles within the entity), ensuring effective communication within the Coordination Center and other operational centers. This guarantees efficient information exchange between operational structures and Civil Protection components at different territorial levels.

Municipal-level emergency areas must be marked with specific signage (to be defined if not already in place), following the Operational Guidelines from the Head of the Civil Protection Department. This signage aims to provide clear instructions in case of need and is categorised into: Municipal-Level Emergency Areas. Municipal emergency areas are marked with specific signage (to be defined if not already in place), following the Operational Guidelines from the Head of the Civil Protection Department. These areas serve different purposes and are categorised as follows:

- Waiting Areas: Safe initial gathering points for the population. These can include squares, parking lots, and open urban spaces to be temporarily used in case of an event.
- Assistance Areas and Centers:
  - Assistance Areas refer to temporary field sites where essential services can be rapidly provided through the setup of tents, field kitchens, sanitary modules, and showers, ensuring the supply of essential services.
  - Assistance Centers cover public or private structures (e.g., schools, exhibition halls, gyms, military facilities) temporarily converted to shelter evacuees.
  - These areas and centers are equipped during emergencies with materials from municipal logistic hubs/warehouses or those managed by provinces/metropolitan cities, regions, or local civil protection systems.
  - Additionally, pre-identified hospitality facilities should be mapped in advance, and agreements should be made with their managers to ensure immediate availability during emergencies.
- Staging Areas for Rescue Personnel and Resources: Gathering points for operators, vehicles, and equipment required for emergency response in the municipality. These areas should, where possible, be close to covered structures (for personnel and equipment) and major road junctions. These areas serve as temporary holding zones in large-scale emergencies before assigning responders to intervention sites.
- Emergency Landing Zones (ZAE): Helicopter landing areas needed for rescue, evacuation, and logistics. Preferably, these should include ENAC-registered helipads that are maintained regularly.
- Critical Points or Risk Areas: Locations where an event may cause public or private safety hazards (e.g., flood-prone underpasses, river confluences near transport infrastructure, bridges with limited clearance, inhabited areas prone to landslides). These areas require on-site or remote monitoring and urgent intervention before or during an event (e.g., road closures, preventive evacuations, temporary flood defenses, landslide protections).
- Observation Points: Secure locations for monitoring events (e.g., hydrometers, rain gauges, or visual observation points).

Municipal territorial monitoring follows national flood emergency supervision and response protocols (per the Prime Ministerial Directive of February 27, 2004). Municipalities establish their monitoring activities according to their organisational autonomy. Under Article 11, Paragraph 3 of the Civil Protection Code, Regions define the organisation of support measures for emergencies listed in Article 7, Paragraph 1, Letter a. Based on specific agreements, the National Fire Department may conduct territorial monitoring when risk levels rise. Personnel assigned to monitoring and surveillance must be properly trained in risk assessment, communication with the CCA (Area Coordination Center) or COC (Municipal Operations Center), and

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emergency response measures. Civil Protection volunteer organisations, coordinated by regional authorities, may also be involved in these activities.

Article 16 of the Civil Protection Code defines the types of risks the National Civil Protection Service covers. For these risks, planning guidelines follow those outlined in this directive, along with any additional specifications provided by sector-specific regulations. The main categories of risk include:

- Hydraulic and hydrogeological risks
- Severe meteorological events
- Dams
- Avalanches
- Seismic risk
- Volcanic risk
- Tsunamis
- Wildfires and wildland-urban interface fires, such as those monitored with 5G-controlled drones in the Torino Hill area.

Additionally, Article 16, Paragraph 2 states that, while sector-specific authorities retain their competencies, the National Civil Protection Service also intervenes in other types of risk, including:

- Chemical, nuclear, radiological, technological, and industrial risks
- Transport-related hazards
- Environmental and health-related risks
- Uncontrolled re-entry of space objects and debris

For these additional risks, emergency planning at various territorial levels focuses on supporting the competent authorities in organisational and population assistance measures.

Specific directives and guidelines are already in place for certain risks, and territorial planning efforts must refer to these, while considering future updates or additional regulations for other risk types.

Industrial risk planning.

For industrial risks, Civil Protection planning specifically refers to the External Emergency Plans (PEE) for high-risk industrial sites, as defined in Legislative Decree No. 105 of June 26, 2015, under the jurisdiction of the Prefectures – Government Territorial Offices. These plans include essential information for the implementation of Civil Protection activities by municipalities, particularly regarding:

- Public information on the specific risk, related scenarios, and self-protection guidelines.
- Population assistance measures.
- Traffic and mobility management in case of an event.

Coastal pollution response

For coastal pollution caused by hydrocarbons or other harmful substances, the Prime Ministerial Decree of November 4, 2010, establishes the National Emergency Response Plan for oil spills and marine pollution.

Annual civil protection monitoring in Torino

The City of Torino conducts annual Civil Protection monitoring, including 5G-controlled drones in BVLOS (Beyond Visual Line of Sight) operations, to assess the current status of Civil Protection planning.

Civil protection authorities make the monitoring data available pending the development of the federated information system called the "National Civil Protection Plan Catalog." This system aims to provide a comprehensive overview of emergency planning updates nationwide and enhance integration among Civil Protection systems at different territorial levels.

Civil protection exercises

Civil Protection drills and exercises are conducted to:

- Verify the effectiveness of Civil Protection planning at different territorial levels.
- Test operational models and response mechanisms.
- Promote awareness of emergency plans among all stakeholders, particularly the general public.

The exercise includes planning, execution, training, knowledge dissemination, evaluation, and improvement. Activities are structured around a document known as the "Exercise Project Document."

This directive replaces the previous Civil Protection Training and Exercise Planning Circular (No. DPC/EME/0041948, May 28, 2010).

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Depending on whether the planned activities are physically executed or just simulated, Civil Protection exercises are classified as follows:

1. Command Post Exercise (CPX)

- Focuses on simulated coordination between operation centers at different levels.
- Involves resource movement simulations to test decision-making processes, communication protocols, and response activation times.
- No real field operations occur, except for activating and monitoring operational centers.

2. Field Exercise (FX)

- Simulates activation, mobilisation, and operational deployment of trained teams or modules.
- Includes real-world field actions and interaction with relevant territorial authorities.
- Comparable to rescue drills, designed to test specific response aspects and learning objectives.

3. Full Scale Exercise (FSX)

- Simulates the full Civil Protection cycle, from early warning and prevention to emergency response and management.
- Requires activation of operation centers at all territorial levels and real field deployments.
- Includes resource mobilisation and direct population involvement.

4. Table Top Exercise (TTX)

- Uses a simulated environment to replicate a disaster scenario or parts of an event.
- Tests decision-making processes, evaluating how teams apply Civil Protection plans and intervention models.
- Typically lasts a few hours to a full day.
- Participants discuss strategies and document responses to various assigned problems or tasks.

5. Discussion-Based Exercise (DBX)

- Similar to CPX, but focused on evaluating and discussing specific procedures.
- Participants jointly review and analyse protocols in a structured debate format.

Exercise Planning Document

A “Exercise Project Document” is created for all exercise types. This document is submitted to the relevant territorial authorities and includes:

- Scenario details
- Involved entities and authorities
- Objectives
- Activity timeline (chronogram)

3.2.2. Modules and software

Following an in-depth market analysis for project purposes, the City of Turin - Local Police Department - Civil Protection, Emergency Management, and Security Division - Drones Unit has adopted an all-in-one web platform compatible with commercial drones. This platform integrates flight management for individual drones and fleets with image analysis within a single solution. The chosen solution is called Dromt Hub.

The selected platform is compatible with most commercial drone brands and models, making it suitable for any use case. It is also fully compatible with the drones identified for the Turin pilot project, specifically the DJI Mavic 3ET, DJI Matrice 30, and SenseFly eBeeX. Additionally, the platform allows for the simultaneous management of multiple drone missions.

For preventive missions using the SenseFly eBeeX drone, flight missions will be managed directly by the drone manufacturer's software. The captured images are uploaded to the platform's cloud servers via a dedicated 5G modem router. The software then processes the images, generating aerial photogrammetry mappings.

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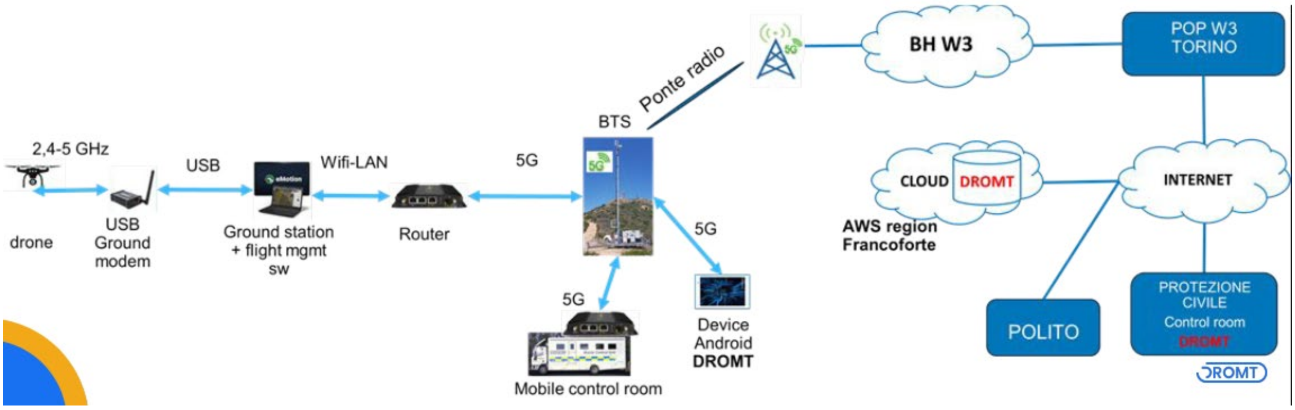

Figure 18. Solution for photogrammetry

The drone is connected to an enterprise-series remote controller with an integrated display for reconnaissance missions after a disaster. A dedicated drone piloting application has been installed and is used directly on the remote controller. The remote controller connects via Wi-Fi LAN to a 5G modem router, enabling communication with the Dromt server for video streaming transmission. If an enterprise-series remote controller is not used, an Android display device (smartphone or tablet) will be required to install and run the drone control application.

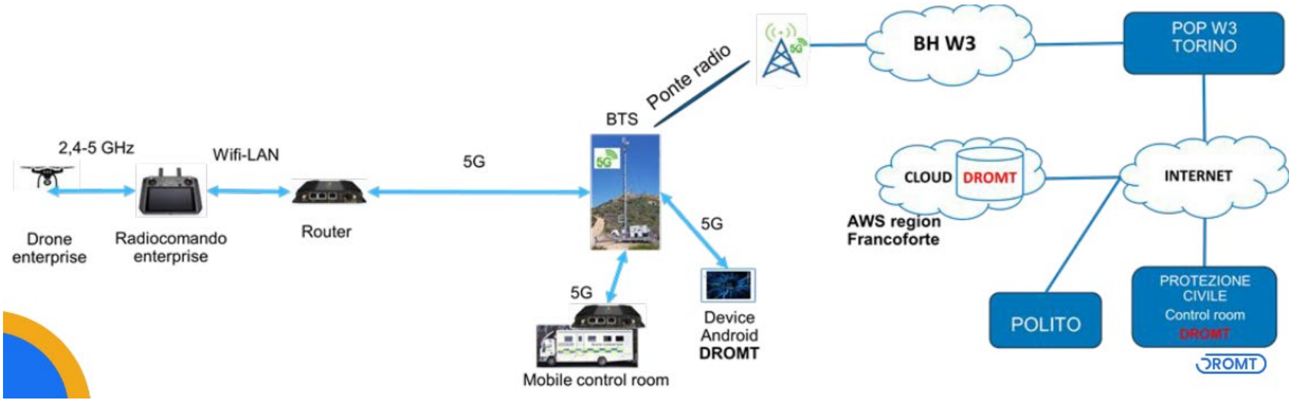

Figure 19. Solution with enterprise-series remote controller

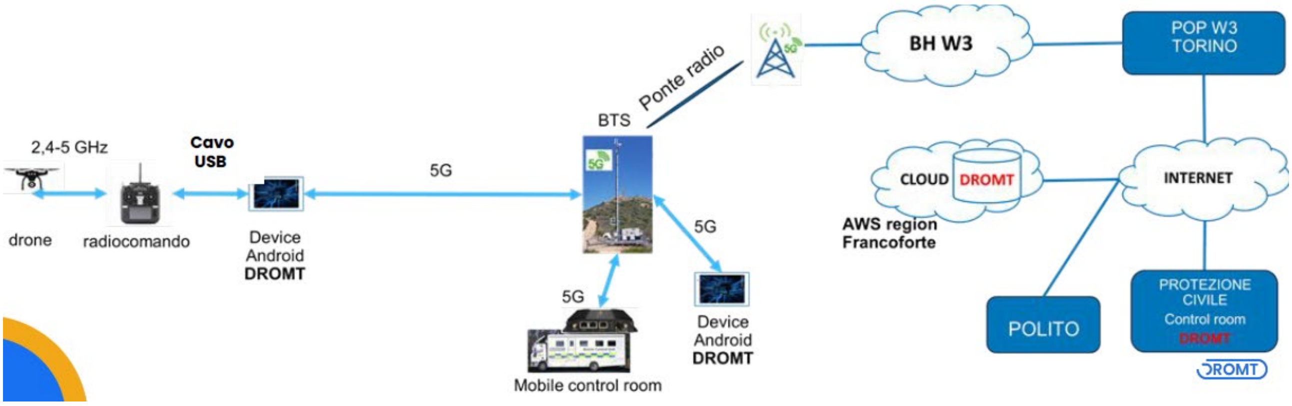

Figure 20. Solution without enterprise-series remote controller

3.3. Lifeguard station design, Riga Use-Case

The 5G4LIVES lifeguard station design in the Riga pilot is structured to enable a highly efficient, technology-driven approach to emergency response and search-and-rescue operations. Integrating drones, docking stations, remote control centre, and a mission management ecosystem ensures a seamless interaction between UAVs and lifeguards. This design allows for real-time surveillance, automated UAV operations, and efficient emergency interventions, reducing response times and enhancing situational awareness.

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Two key operational locations, Ķīšezers and Vecāķi—host the drones infrastructure, ensuring full coverage of the designated search-and-rescue areas. Each location has drone docking stations, which function as operational hubs for UAV deployments. These stations provide automated battery recharging, eliminating manual handling and reducing drone downtime. The ability to quickly swap batteries with fully charged units ensures that drones remain available for missions with minimal interruptions. The UAVs in these locations follow a pre-programmed patrol schedule, automatically scanning the area for potential incidents while maintaining direct connectivity with the Remote Operations Control Centre in Riga through the 5G network.

The Remote Operation Control Centre is the command hub where two operators (remote pilots) manage UAV operations. The facility includes an operations room for mission planning, UAV supervision, and real-time intervention when necessary. Operators monitor live video feeds and telemetry data from multiple UAVs, ensuring that any detected emergency is immediately assessed and responded to. The ROCC is equipped with mission control software, which allows for precise coordination of drone movements, flight planning, and automation of search-and-rescue scenarios. Artificial intelligence-powered analytics can be integrated into the system, providing incident detection accuracy and decision-making based on UAV-captured data.

A critical aspect of the system is 5G connectivity, which ensures ultra-low-latency communication between UAVs and the ROCC. The network supports real-time streaming of video feeds, continuous data transmission, and instant remote piloting. Unlike conventional radio-based UAV operations, 5G enables drones to operate reliably beyond visual line of sight (BVLOS), ensuring full coverage of the operational areas without direct line-of-sight constraints. This technological advantage significantly increases the efficiency of search-and-rescue missions, particularly in scenarios where rapid intervention is crucial.

Integrating UAV operations with the broader 5G4LIVES emergency response ecosystem allows seamless coordination with municipal emergency services and monitoring platforms. The Remote Operation Control Centre can be connected to external police video monitoring systems, enabling a shared surveillance and emergency response environment. This feature ensures that all stakeholders (police, lifeguards, and other relevant personnel) have synchronised access to real-time UAV footage and alerts. The ability to relay live video and telemetry data to municipal emergency services enhances inter-agency coordination, ensuring that critical decisions are made with accurate, real-time information—the lifeguard station design centres on efficiency, automation, and rapid emergency response. The UAVs conduct routine patrols, continuously scanning the area for signs of distress. If an emergency is detected, the drone can alert the lifeguards on-site or relay the information to the ROCC for assessment. In cases requiring immediate intervention, lifeguards receive real-time GPS coordinates and live aerial footage, allowing them to reach the affected individual as quickly as possible. The UAVs also serve as communication relays, broadcasting instructions through onboard loudspeakers to guide individuals in distress or provide instructions to the public in high-risk situations.

The mission control software installed in the ROCC provides a centralised interface for all UAV operations. The platform allows operators to view real-time UAV telemetry, adjust mission parameters, and activate emergency response protocols.

The design philosophy behind the lifeguard station is to create a scalable, automated, and highly efficient emergency response system that can be expanded to cover additional locations. Using 5G connectivity, AI-based monitoring, and UAV automation establishes a model for future search-and-rescue infrastructure, demonstrating how technology can increase safety and response efficiency.

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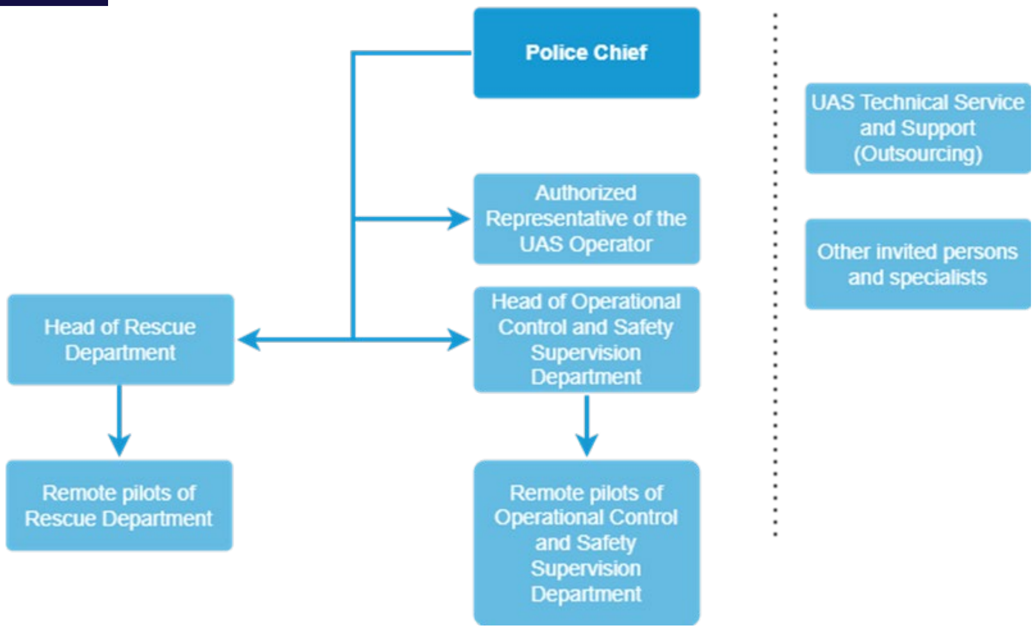

Figure 21. Organisational structure in the Remote Operation Control Centre.

3.4. Image processing solution, Riga Use-Case

Data flow architecture.

Based on the current specification of the UAV, Computer vision and Machine learning calculations will be done in the Riga municipal police infrastructure, colocated with their video management system to provide wide bandwidth between those two systems. CV/ML calculations will be done in LMT infrastructure with a high-bandwidth VPN connection between the two infrastructures as a backup solution.

Therefore, overall architecture would be as follows:

- Video stream and position data from the UAV is sent through the cellular network to the RMP video management center
- Riga Municipal Police's existing VMS is integrated (one of the WP tasks) with the LMT CV/ML system.
- Video analysis is performed, and alerts are calculated
- Alerts are returned from LMT CV/ML software to the RMP VMS to be displayed to the operators and to take further actions if required.

Target use-cases and objects:

- In an emergency situation on the water, the following objects are detected: swimmers, buoys that mark safe swimming zones, and watercrafts. Alerts will be sent if the swimmers are outside a safe region or the watercrafts are inside regions marked with buoys.
- For winter situations: holes in the ice will be detected as well as persons on the ice surface
- For crowd flow estimations, people will be counted in various situations from the UAV's typical positions high above the ground.

Model training:

- Models are trained using open-source data with similar features, and standard novel ML deep neural network models (e.g., Yolo vX) will be utilised as a basis.
- Those data sets are augmented with real images from locations in Latvia, which is necessary to allow the model to perform better in the local environment.
- After that, the model will be deployed for testing, and additional footage will be obtained, again used to augment the model.
- As a last phase, during testing, cases where detections are not of satisfactory quality will be gathered, targeted data reflecting such situations will be gathered, and the model will be trained and constantly improved to increase detection quality.

Target measurements:

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- Flow counting: the estimated accuracy of the number of people in the crowd in typical situations with trees partially blocking the UAV view is +/—30% of the actual number of people in the crowd.
- Flow counting: estimated accuracy of number of people in the crowd, in a situation where the UAV is stationary and there are no obstructions for the UAV view +/- 5% of the actual number of people in the crowd
- Summer scenario: In calm weather scenarios, swimmers are detected and tracked if they remain in the UAV's field of view, and their position is estimated to be within/out of safe zone bounds marked by buoys.
- Winter scenario: Alerts are sent to the operating center if the ice cover is deemed dangerous and people are detected on the ice zones.

CONCLUSIONS

The project opted for a comprehensive lifeguard management platform that unifies all technological components – drones, connectivity, data processing, and user interface – into a single system. The lifeguard platform is specified to provide several core functionalities: (1) mission planning – the ability to define drone flight plans on maps, set waypoints or search patterns, and input emergency mission parameters; (2) real-time command and control – a control center interface where operators can supervise ongoing drone operations, with live telemetry and video feeds displayed, and intervene with manual commands if needed; (3) live video streaming – integration of low-latency video from the drones directly into the platform, viewable by multiple users (e.g., incident commanders, on-site lifeguards via tablets, etc.) simultaneously; (4) data analytics – upon flight completion (or even during flight), the platform can automatically process collected imagery or sensor data to produce useful outputs such as stitched maps, alerts (e.g., detection of a person or object), or measurements (like area of a polluted spill, etc.). The platform adheres to relevant standards and scenarios: for instance, it supports the STS-02 scenario (standard European scenario for drones) meaning it has features like predefined emergency procedures and geofencing appropriate to that scenario, and it complies with Remote ID data handling (it can display drone ID and position info, likely interfacing with UTM systems). The specifications also emphasise user management and security: the system must accommodate multiple user roles (drone pilot, lifeguard supervisor, etc.) and keep data secure, which is implied by the requirement of running in controlled IT environments (on-premise or trusted cloud).

The selected platform effectively merges what could have been separate subsystems. For example, rather than using one application for drone control and another for video streaming, the platform provides a single dashboard where a user can launch a drone mission and simultaneously watch the live video on the map. This integrated design means that when a lifeguard coordinator sees something in the video, they can immediately mark a location or redirect the drone from the same interface. Remote Operation Control Centre houses the Drone Control & Operations System – the platform's command centre setup. In practice, this could be a room with large screens showing maps and video, where operators use the platform to manage everything in real time. Implementing the platform on virtual machines or cloud services was an important solution to ensure scalability. As specified, it can run on VMware vSphere or Microsoft Azure, meaning it's been containerised or virtualised. This allows the platform to be easily scaled (e.g., add more processing power if more drones are added in future) and to be maintained with high availability. Compliance with emergency protocols - the platform's design considered existing emergency management structures and procedures. In Italy, for example, civil protection operates at national, regional, and municipal levels, using established protocols. The section describes how the platform fits into municipal civil protection plans in Turin, ensuring the drone operations complement traditional rescue efforts rather than work in isolation. This involved mapping out how information flows: e.g., if the platform detects an incident via drone, how that alert goes to the city's emergency services workflow. Ensuring this compatibility was a non-technical but key integration solution implemented by the project.

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4. 5G4LIVES OPERATIONS ENVIROMENT

The Operation Environment section of 5G4LIVES focuses on the conditions and systems necessary to conduct safe drone missions beyond visual line of sight and the project's approach to environmental sustainability and impact. It introduces the Unmanned Traffic Management (UTM) integration solution, critical for coordinating BVLOS drone flights with airspace rules and ensuring safety. This includes describing how the project complies with regulatory scenarios (like predefined EU standard scenarios or specific flight authorisations) and the tools used to plan and monitor drone trajectories. In parallel, the section examines the incorporation of green technologies in the project's telecom infrastructure and outlines principles for assessing the environmental impact of using drones in lifeguard services. By addressing both the technical flight environment and the ecological footprint, the project demonstrates a commitment to responsible innovation.

This section presents the solutions for managing drone flights and minimising their environmental impact. It details the UTM/BVLOS component solutions, such as how a UTM platform or specialised software tracks drones, provides real-time situational awareness on airspace use, and allows remote interventions during flight—an AI-powered solution for recognition automation is described. The section also analyses any green technology measures (for instance, energy-efficient network equipment or renewable power sources for drone infrastructure). Additionally, impact assessment principles are outlined, covering how the project measures carbon footprint, noise disturbance, and battery waste management, ensuring that drone operations remain environmentally conscious.

4.1. UTM / BVLOS COMPONENTS SOLUTION

4.1.1. UTM solutions Turin Case

As specified in document D2.2, the flight operations conducted for the demonstrations must comply with UTM requirements.

The operations will be carried out using STS and PDRA scenarios, meaning the regulatory constraints regarding UTM functionalities can be met through the D-Flight portal, which serves as the Italian UTM platform. However, in the 5G4LIVES project, additional support platforms will be used, integrating advanced functionalities and offering services typical of a UTM.

As detailed in previous sections, the DROMT platform will be used during the demonstrations as a tool for Civil Protection, both for managing the flight mission and for visualising real-time and post-mission data.

DROMT offers several UTM-like services:

- Enhanced situational awareness: The UAS operator can visualise the map's operational area and planned mission, which helps the operator be more aware of the flight operation.
- Drone real-time position: The UAS operator can monitor the drone's position and telemetry in real time. The real-time position is displayed on the map, increasing situational awareness. This functionality allows the operator to verify whether the drone follows the planned mission. Moreover, the DROMT platform permits to track the positions of all drones managed by the platform.
- Remote drone control: The operator can intervene by sending high-level commands to the drone, such as landing, hovering, or setting a new target. This functionality is essential for BVLOS operations.

As detailed in the previous section, a tool implementing the BVLOS mission planning, validation, and monitoring methodology will be developed in addition to the DROMT platform. This tool also includes a UTM-like service called Risk-aware situational awareness, which further enhances situational awareness during mission planning and execution by displaying the risk distribution on the map.

4.2. GREEN TECHNOLOGIES AND METHODS IMPLEMENTATION

4.2.1. Tourin Case

During the 5G4LIVES project, for what is strictly linked to the telco components, the use of green technologies will not be possible given the particular nature of the BTS that will be built. Since it is a mobile BTS set up specifically for the project, it will not be possible to use photovoltaic panels or other green energy sources. Inside Wind Tre, a Corporate ESG (Environmental, Social and Governance) Plan has been implemented since 2022. Among the goals of this plan, there is a commitment to environmental protection and the target to eliminate scope 1 and 2 (Scope 1: direct emissions from the organisation's activities; Scope 2: indirect emissions related to the purchase of electricity) emissions by 2030.

This result has been reached thanks to the strong focus on optimising network infrastructure operations and maintaining stable electricity consumption despite data traffic consumption growth of more than 6 times compared to 2017. With the introduction of the new ESG objective "Sustainable Supply Chain", we are also involving the supply chain in constantly improving our environmental and social impact. Regarding the digital sector, its environmental impact is growing quickly. The causes include the impact of technologies such as AI, associated significant increases in energy consumption, and the effects of the disposal of technological devices.

The telecommunications industry's environmental impact is expected to rise with the number of devices and infrastructures for data transit. A TELCO operator's main impact lies in its energy requirements.

Actions in progress:

• A gradual increase in the purchase of green energy
• Continuous modernisation of the radio access network to ensure maximum energy efficiency
• Upgrade of the company car fleet to include low emission vehicles
• Offsetting of residual CO2 emissions

At Wind Tre, over 95% of energy consumption is attributable to network infrastructure. In comparison, just 2% of energy consumption comes from the offices, and the remaining 3% from fuel consumption for the corporate fleet. Due to the widespread nature of the network, it is mainly supplied with energy purchased from the national grid and, to a lesser extent, by a few company-owned photovoltaic plants. Wind Tre S.p.A. has set up an energy management system in line with the international standard ISO 50001 to ensure that it uses energy resources increasingly efficiently.

Wind Tre S.p.A. has its carbon footprint, an indicator that enables the measurement of the quantity of greenhouse gas emitted directly and indirectly. It is certified by an independent third party by the international standard ISO 14064.

Following the creation of the unified Wind Tre company, the organisation set itself the goal of modernising the entire national network to make it increasingly energy efficient and ready to embrace the technologies and services of the latest generation. The mobile radio network equipment has been replaced with the latest generation of energy-efficient equipment, equipment subject to variable operational loads has been equipped with increasingly advanced energy-saving features, and the infrastructures in which the equipment resides have been modernised with exterior configurations which require lower levels of cooling energy. The radio base stations and the large plants have been equipped with Free Cooling systems, which use external air to cool the equipment, thus reducing the air conditioning units' energy consumption and extending their life cycle. Once the modernisation and energy efficiency improvement of the entire mobile radio access network was completed, the company launched a project dedicated to monitoring and verifying its stations' energy efficiency. Thanks to the continuous automated analyses provided by the monitoring, the company can now determine the specific areas of intervention and the direct actions needed to further improve its energy efficiency figures. For example, the company has developed an automated tool which dynamically determines where to take action to redirect traffic so that specific equipment can be placed in smart sleeping mode. In contrast, other equipment continues to provide a service, thus reducing the use of infrastructure to save energy.

A program to replace power stations with technologically more advanced systems that offer improved performance was launched in November 2023.

4.2.2. Riga Case

The 5G4LIVES Platform aims to extend emergency response capabilities by integrating advanced 5G and UAV technologies. One of the critical components of this infrastructure is the provision of reliable, sustainable, and efficient power sources to ensure the sustainable 5G4LIVES ecosystem working in a greener and safer environment. Hydrogen fuel cell systems emerge as a promising solution to meet these energy demands, offering potential applications in:

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- In 5G BS infrastructure as backup supply solution, ensuring uninterrupted network coverage, especially in remote or disaster-affected areas where grid reliability is compromised.
- A power supply unit for UAV Docking Stations, providing autonomous UAVs with a consistent and rapid recharging mechanism essential for continuous operations.
- A power supply solution for mobile command units (driven by UAV S&R missions), delivering portable and dependable power for on-site emergency response teams, facilitating real-time communication and coordination.

Hydrogen fuel cells operate through an electrochemical reaction between hydrogen and oxygen, generating electricity with water and heat as byproducts. Their high energy density makes them a suitable alternative to conventional power sources, particularly for compact and lightweight applications. In the context of UAV docking stations, operations Centers infrastructure, and 5G base stations, the reliability and efficiency of hydrogen power provide a compelling advantage over diesel generators and traditional grid-based energy supplies. As an advantage, hydrogen solution provides a substantial amount of energy per unit mass, making it suitable for applications requiring compact and lightweight power sources; fuel cell systems can be configured to meet varying power requirements, from small-scale UAV charging stations to large-scale base stations. Additionally, with fewer moving parts than traditional generators, hydrogen solutions offer more durability and lower maintenance needs.

As a possible solution for the integration possibilities study, the Ballard FCgen H2PM 10kW system was analysed as an alternative solution for the Operation Locations infrastructure components, supplies unit and backup for BS. The system operates with an efficiency range of 50-60%, compared with traditional diesel generators, which typically achieve 35-40% efficiency.

Operational costs for the solution depend on the cost of hydrogen fuel. Hydrogen fuel prices within the European Union fluctuate based on production methods and market dynamics. Hydrogen fuel cell running costs per kWh depend on:

- Hydrogen price aspect – the latest EU estimates (2024-2025) from EC reports [1] Indicate green hydrogen prices between €2.94 and €7.90 per kilogram (kg).
- Regarding energy efficiency,1 kg of hydrogen contains ~33.33 kWh. Fuel cell efficiency is typically 55%, meaning only 55% of the hydrogen's energy is converted into usable electricity.

The usable energy per kg of hydrogen is 18.33 kWh per kg. Cost per kWh calculation – at €2.94 per kg: 0.16 €/kWh; at €7.90 per kg: 0.43 €/kWh.

Table 16. Comparison of traditional grid vs hydrogen fuel system

Aspect	Traditional grid electricity (Latvia, 2025)	Hydrogen fuel cells (EU 2024-2025)
Cost per kWh	€0.09	€0.16 - €0.43
Reliability	Dependent on grid stability	Independent, resilient
Carbon emissions	Varies with energy mix	Zero emissions
Infrastructure readiness	Fully developed	Requires hydrogen storage & distribution / or supply chain for "cartridges"
Scalability	Limited without expansion	Off-grid, scalable

Key findings for hydrogen power supply technologies deployment

Cost comparison

- Traditional grid electricity (€0.09/kWh) is currently cheaper than hydrogen fuel cell energy (€0.16 - €0.43 kWh). In Latvia, hydrogen fuel costs 1.8 to 4.8 times more per kWh than grid electricity. The future cost of hydrogen (by 2030) will decrease, making it a more viable alternative in off-grid applications.

Energy security and reliability

- Grid power is cost-effective but vulnerable to disruptions (e.g., power outages, grid failures). Hydrogen fuel cells provide autonomy and backup power, ideal for emergency response stations and UAV hubs.

Environmental impact

[1] Renewable and low-carbon hydrogen; State of play and outlook, EPRS | European Parliamentary Research Service

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- Hydrogen fuel cells offer zero emissions, aligning with Latvia's and the EU's Green Hydrogen Strategy. Grid electricity's emissions depend on Latvia's energy mix (if fossil fuels dominate, carbon impact remains high).

Long-term hydrogen viability

- If hydrogen production costs fall below €2.50/kg, hydrogen fuel cells could become cost-competitive with grid electricity. Investment in local hydrogen infrastructure is necessary to reduce reliance on imports and lower distribution costs.

Currently (2024-2025), hydrogen fuel cell energy is more expensive than traditional grid electricity in Latvia. However, hydrogen remains a critical backup power solution for remote 5G base stations, emergency drone hubs, and disaster response sites, where energy independence is crucial. Hydrogen fuel cells are a long-term investment for off-grid and resilient energy infrastructure that can complement grid electricity, ensuring sustainability and uninterrupted operations. The economic feasibility of hydrogen will depend on future cost reductions, EU funding support, and local production advancements.

Hydrogen (especially green) remains more expensive than grid electricity but has long-term sustainability benefits. Blue and grey hydrogen are already cost-competitive with traditional electricity prices, particularly in areas with high energy demand or unreliable grid access. Grid electricity remains the cheapest for stationary infrastructure, but hydrogen offers a viable alternative for remote, mobile, or emergency applications. Infrastructure investment and subsidies (such as the EU's CEF funding) can reduce hydrogen costs over time.

Potential in 5G4LIVES Riga Use-Case

Despite hydrogen's potential as a sustainable energy source, its feasibility for the 5G4LIVES project is challenging due to high costs, infrastructure challenges, energy inefficiencies, and technological constraints. A primary argument against hydrogen-powered energy for 5G4LIVES infrastructure is the significantly higher cost per kWh than grid electricity. The latest Nord Pool electricity market data shows that the average electricity price in Latvia (2025) is €90/MWh (€0.09/kWh) (AST Latvia, 2025).

Hydrogen cost breakdown

Hydrogen production costs vary depending on the method used:

- Green hydrogen (electrolysis): €3.50 - €6.00/kg
- Blue hydrogen (natural gas + carbon capture): €1.50 - €3.00/kg
- Grey Hydrogen (conventional natural gas): €1.20 - €2.50/kg

Since 1 kg of hydrogen produces ~33.6 kWh of energy, the cost per kWh is calculated as follows:

- Green hydrogen (€4.00/kg): €0.119/kWh
- Blue hydrogen (€2.00/kg): €0.059/kWh
- Grey hydrogen (€1.50/kg): €0.045/kWh

Table 17. Comparison with Grid Electricity

Energy Source	Cost per kWh (€)
Grid Electricity (Latvia, 2025)	0.09
Green Hydrogen	0.119
Blue Hydrogen	0.059
Grey Hydrogen	0.045

Even the cheapest grey hydrogen is barely competitive with grid electricity. Green hydrogen is significantly more expensive, making it economically unviable for 5G4LIVES, which requires cost-efficient, high-availability energy. Hydrogen energy conversion involves multiple stages, each causing efficiency losses. A fuel cell typically operates at 50-60% efficiency, meaning nearly half the energy is lost in conversion. In contrast, direct grid electricity usage is almost 100% efficient.

Table 18. Energy efficiency breakdown

Energy Process	Efficiency (%)
Electrolysis (Converting electricity → hydrogen)	65-75%
Hydrogen transport and storage	80-90%
Fuel cell conversion (hydrogen → electricity)	50-60%

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Overall system efficiency	~30-40%

This means that for every 100 kWh of electricity used to generate hydrogen, only ~30-40 kWh of useful energy is ultimately available. By contrast, grid electricity directly results in 95-99% efficiency, making hydrogen an energy-wasting alternative. Hydrogen fuel cells waste more than half of their original energy due to conversion losses, making them highly inefficient for operations where power efficiency is crucial. (*International Energy Agency (IEA), Global Hydrogen Review 2024*.) The 5G4LIVES project requires a stable and widely available energy supply. However, Latvia lacks hydrogen refueling and distribution infrastructure, making implementation logistically challenging and cost ineffective.

High maintenance and safety risks

Hydrogen is a highly flammable gas, requiring stringent safety measures. Fuel cells deteriorate faster than batteries or grid infrastructure, leading to higher maintenance costs.

Key safety and maintenance issues:

- Leakage risks: Due to its small molecular size, hydrogen leaks more easily than other fuels, increasing the risk of fire and explosion.
- Specialized storage and handling require high-pressure tanks or cryogenic cooling, making maintenance complex and expensive.
- Over time, hydrogen fuel cells lose performance efficiency, requiring more frequent replacements than batteries or traditional grid connections.

Hydrogen fuel cells require higher maintenance and introduce safety concerns, making them less reliable than grid electricity.

In the 5G4LIVES scenario (Riga Use Cases), four drones will be deployed across two locations. With such a fleet size, investments in hydrogen-based power supply systems for deployment and maintenance are not cost-effective, even in the medium term.

Considering running costs, investments in hydrogen technology could be feasible if UAVs powered by fuel cells were used. However, the scenario design does not account for such platforms. Therefore, considering the fleet size, area of operations, and cost comparison, the hydrogen power supply will not be integrated for the Riga Use Case.

However, hydrogen-based technologies could be integrated if the solution is scaled up, where the fleet size reaches 10 or more platforms, covering larger operational areas and requiring higher reliability and backup power.

4.3. Impact assessment principles for drone operations

Environmental impacts and carbon footprint.

Drone operations can have a lower direct environmental impact than traditional manned systems (e.g. helicopters or patrol boats) since electric drones produce no on-site emissions. However, a holistic impact assessment considers the carbon footprint of the drone program, including both direct and indirect emissions. The carbon footprint measures all greenhouse gases emitted by the activity, typically expressed as CO_2 equivalent. This includes Scope 1 emissions (direct emissions from operations) and Scope 2 emissions (indirect emissions from purchased energy), as well as relevant upstream sources (manufacturing of drones/batteries, often categorised as Scope 3). In practice, calculating the carbon footprint of drone operations involves estimating energy use (e.g. electricity to charge batteries or fuel for generators) and applying appropriate emission factors. For instance, if drones are charged from the grid, the carbon intensity of the grid electricity (gCO_2 per kWh) is used to convert electricity consumption into CO_2 emissions. Adhering to standards like ISO 14064 helps ensure a consistent and transparent methodology for quantifying these emissions. Beyond carbon, the impact assessment should also consider noise and wildlife disturbance. In the 5G4LIVES Riga use-case (Vecāķi Beach), operations are coordinated with environmental authorities to avoid sensitive periods for wildlife, limiting drone activity near nature reserves when needed. These measures ensure the drone program aligns with environmental protection goals while fulfilling its lifesaving mission.

Comprehensive cost analysis (operations, maintenance, automation)

A thorough cost assessment covers all phases of drone operations. Operational costs include routine expenses to fly and manage the drones. Electricity or fuel to power drones and their ground infrastructure is

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a primary component, electrically powered drones have relatively low energy costs per mission (on the order of a few euro-cents per flight, e.g. approximately €0.10–€0.50 in energy per "delivery"-sized mission). Connectivity and data costs (such as 5G network usage or cloud services for data storage) also fall under operational costs, as do fees for necessary certifications or airspace authorisations. Insurance and regulatory compliance costs must also be budgeted (comprehensive drone insurance can be ordered in thousands of euros annually depending on coverage and risk). Labor is another operational cost: a pilot must be on-site with traditional drones, but in the 5G4LIVES scenario, remote pilots oversee operations. This automation and remote operation can shift the cost structure from many field personnel to a few centralised operators.

Maintenance costs include upkeep of UAVs, docking stations, and related equipment. Drones require regular inspections, part replacements (propellers, motors), firmware updates, and battery replacements over time. Manufacturers recommend maintenance schedules based on flight hours or cycles to ensure reliability. In 5G4LIVES, specialists combine daily basic checks (e.g., lifeguards ensuring a drone's rooftop dock is clear of debris or ice) with scheduled technical maintenance. Annual maintenance and repair costs for a professional drone can reach several thousand euros per drone, often estimated at ~€4,500–€13,500 annually depending on usage intensity. Additionally, support infrastructure like the docking/charging stations has maintenance needs (e.g., keeping charging contacts clean and software upkeep).

Automation effects

The introduction of automation and remote operation can significantly influence costs. On one hand, automation (such as pre-programmed patrol flights and autonomous charging) can reduce labor costs and increase efficiency – one remote pilot can supervise multiple drones simultaneously, effectively multiplying oversight capacity without equivalent staffing increases. This is a key benefit in 5G4LIVES: routine patrols run largely automatically, with a remote pilot only intervening or taking manual control when necessary, allowing a small team to manage a fleet. Fewer on-site pilots means lower travel and personnel deployment expenses. On the other hand, advanced automation requires upfront investment in technology (robust drone control software, AI analytics, docking stations) and training. These capital and development costs must be amortised over the project. The cost analysis must balance the high initial investment in an automated, networked drone system against the operational savings and performance gains it brings. Regular review of cost KPIs (cost per hour of operation, cost per intervention, etc.) helps ensure the system remains cost-effective while maintaining safety and reliability.

Circular economy principles (battery lifecycle & component recycling)

Implementing circular economy principles in the drone program helps minimise waste and environmental impact over the system's life. A key focus is the battery lifecycle. Drones in 5G4LIVES rely on lithium-based batteries, which have finite charge-discharge cycles. An impact assessment methodology includes plans for extending battery life (through proper charging practices and rotation of battery use) and end-of-life management. After a battery's usable life in high-performance drone operations, it could be repurposed for less demanding applications (secondary storage, training equipment) as a second-life use, delaying disposal, ultimately, worn-out batteries must be disposed of safely and recycled. Lithium-ion batteries contain valuable and hazardous materials like lithium, cobalt, and nickel that should not enter landfills. Proper recycling recovers these materials – reducing the need for new raw material extraction – and prevents toxic substances from polluting soil and water. This aligns with circular economy goals by keeping materials in use and out of waste streams. Recovering battery materials for reuse in new batteries directly *"supports a circular economy"* by reducing overall waste.

Beyond batteries, the drones and their components are also addressed via circular principles. Design for longevity and recyclability is encouraged: drones and docking stations should be built modularly, allowing damaged parts to be replaced without discarding the entire system. Extending the product lifecycle through repairs, refurbishments, or upgrades is cost-effective and eco-friendly. For example, if a drone's airframe is intact, upgrading only the payload or replacing motors can keep it operational for years, avoiding the waste of full replacement. When components reach end-of-life, they are treated as electronic waste: the project can engage certified e-waste recyclers to ensure that metals, plastics, and circuit boards are recycled or disposed of according to best practices. Some drone manufacturers or suppliers offer take-back programs to reclaim used equipment for recycling or parts harvesting, which 5G4LIVES can leverage to close the loop. The project

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reduces its environmental footprint by planning for battery take-back and component recycling. It aligns with broader sustainability and circular economy initiatives in the electronics sector.

Conclusions

The project team addressed the operational environment in two directions: flight safety management for BVLOS drone operations and environmental sustainability of the deployed technology. A key decision for drone operations was to operate under standard scenarios (STS) and predefined risk assessments (PDRA) as per EU regulations, ensuring all flights are within a legal and safe framework. This meant choosing the STS-02 scenario (BVLOS over controlled ground area) for routine operations and preparing Specific Operations Risk Assessment (SORA) documentation for any flights outside standard scenarios. The Italian use-case would use D-Flight, Italy's official U-space/UTM platform, to log flight plans and obtain necessary clearances, while augmenting it with additional tools for more advanced monitoring. Another crucial decision was integrating an internal UTM-like system (DROMT) to provide services unavailable in the basic UTM – such as real-time drone tracking on custom maps, and risk visualisation – to support the civil protection operators during missions. On the environmental side, the project prioritised standard telecom infrastructure for reliability over experimental green tech solutions in the short term. For example, Turin's hillside deployment went with a diesel-powered or grid-powered mobile base station due to practical constraints, rather than attempting solar panels or wind generators, which might compromise the continuous 5G service. Instead, the project aligns with the telecom operator's broader ESG commitments (like Wind Tre's 2030 zero-emission targets) to offset or improve sustainability over time. Simultaneously, the team decided to implement a comprehensive impact assessment framework to evaluate the environmental effects of using drones for lifeguarding – covering factors such as carbon footprint, noise pollution, and effects on wildlife. As part of the action plan, this would inform guidelines and best practices (for instance, scheduling drone flights to avoid disturbing bird nesting seasons at the lake).

The Consortium also developed a Risk-aware Situational Awareness tool to support BVLOS and UTM. This tool uses the risk assessment data (likely from SORA analysis or predefined risk maps of the area). It overlays a "risk map" onto the operational area in the planning software. For example, it could show areas in red where flying over uninvolved people is dangerous or where potential ground impact would be worst (like a crowded beach segment), enabling pilots to plan routes that minimise risk exposure. This forward-looking approach means risk mitigation is built into the mission planning stage, not just handled through regulations. The section also examined incorporating environmentally friendly technologies into the 5G4LIVES infrastructure. The conclusion was that for the immediate demonstration, the critical requirement of reliable connectivity took precedence; thus, the mobile base station and other equipment used conventional power sources. However, the project documented future-looking commitments: Wind Tre's ESG Plan to eliminate Scope 1 and Scope 2 emissions by 2030 is referenced to show that the telecom aspects will transition to renewable energy over time.

On the drone side, electricity-powered drones are inherently lower-carbon than fuel-powered vehicles for patrol, but the project still considered the indirect impacts. One highlight is the plan to extend battery lifespan and ensure proper battery recycling – essentially a circular economy principle applied to drone operations. The project reduces waste and environmental harm by managing charge cycles and end-of-life processing for drone batteries. Additionally, the concept of using hydrogen as an alternative energy explored for feasibility, though not implemented in this phase. The operations environment conclusions stress that while the current setup uses traditional power, it's designed to be upgraded with greener alternatives when feasible. To responsibly deploy drones in public safety, 5G4LIVES established a set of impact assessment principles. The project calculates the greenhouse gas emissions associated with drone operations. While drones produce negligible emissions during flight (being electric), the assessment accounts for indirect emissions – for instance, the electricity generation for charging batteries, manufacturing and maintenance of drones, and the operation of network infrastructure. This comprehensive carbon accounting ensures the project understands the true environmental trade-offs of drones versus traditional methods (like police patrol boats or helicopters with a far higher fuel burn). Drones generate noise that can disturb people and animals. The impact assessment includes monitoring noise levels and setting operational guidelines to mitigate disturbances. In the Riga use-

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case at Vecāķi Beach, the team coordinated with environmental authorities to avoid flying drones during sensitive wildlife periods (e.g., bird nesting season or when migratory birds are present). The operations environment solutions are aligned with the upcoming U-space regulatory framework in the EU, which integrates drones into controlled airspace with services like network identification, geo-awareness, and flight authorisation. By using D-Flight and adding UTM-like extensions, 5G4LIVES is effectively a pilot of "near" U-space concepts at a local level. This positions the project at the forefront of implementing these emerging standards for drone traffic management in a real use-case. Introducing formal risk assessment tools (SORA, risk maps) into daily drone operation fosters a safety-first culture. Technically, it requires collecting data about the operational area (population densities, critical infrastructure locations, etc.) and using software to evaluate mission risk.

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5. 5G4LIVES LIFEGUARD ACTION PLAN

The Lifeguard Action Plan section translates the technical capabilities of 5G4LIVES into actionable strategies and performance targets for lifeguard operations. It introduces a set of tactical Key Performance Indicators (KPIs) to quantify how much the new 5G-connected drone system improves emergency response outcomes. Readers are presented with response times, coverage areas, detection rates, and resource efficiency metrics to understand the expected gains from integrating drones into lifeguard duties. Moreover, this section describes the revised workflows and procedures that lifeguard teams will adopt: from the moment an incident is detected, through drone deployment and live monitoring, to the coordination between drone operators and ground rescuers. The tone is forward-looking and practical, outlining how day-to-day lifeguard operations will change and how success will be measured under the 5G4LIVES system.

5.1. Lifeguard work efficiency assessment and KPI

5.1.1. 5G4LIVES efficiency KPI and measurement

The 5G4LIVES project integrates UAVs with lifeguard operations to improve performance in situational awareness, response time, and overall rescue efficiency. To evaluate its effectiveness, the following Key Performance Indicators (KPIs) are defined with specific measurements, indicators, and expected outcomes.

NOTE: Depending on the full integration results and demos analysis, the KPIs could be revised during the next actions in the 5G4LIVES project.

Table 19. Operational efficiency KPIs

KPI	Measurement method	Indicator	Expected outcome
UAV deployment time	Time from distress signal to UAV launch	Minutes, seconds (m,s)	≤ 40 seconds
UAV response time	Time from launch to reaching the incident zone	Minutes, seconds (m,s)	-
Drone availability rate	% of time UAVs are operational (vs. downtime)	% of uptime	≥ 95%
Flight success rate	% of flights completed	% of missions completed	≥ 98%
Lifeguard response acceleration	Reduction in time for lifeguards to reach incidents	% reduction vs. pre-UAV operations	≥ 30%
Operational coverage expansion	% increase in monitored areas	% of coastline/lake covered	+50% vs. manual patrol
Detection accuracy	% of incidents UAV successfully detects	% of detected incidents	≥ 90%
Victim location Time	Time from distress alert to visual confirmation	Minutes (min)	≤ 2 min
Search area reduction	Reduction in area searched manually	% reduction in area covered manually	≥ 40%
Successful UAV-assisted rescues	% of rescues where UAV played critical role (support decision-making)	% of total rescues supported	≥ 70%
Time saved in search missions	Reduction in search operation time	% decrease in minutes taken	≥ 50%

Table 20. Communication and coordination KPIs

KPI	Measurement method	Indicator	Expected outcome
Data transmission latency	Average latency in UAV live feed	Milliseconds (ms)	≤ 100 ms
Video stream uptime	% of operation time with uninterrupted feed	% uptime	≥ 98%

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Remote pilot-lifeguard coordination	% of operations with seamless UAV-lifeguard handovers	% of successful coordination	≥ 95%
Command center response time	Time from drone detection to emergency service alert	Seconds (s)	≤ 6 sec

Table 21. Safety and compliance KPIs

KPI	Measurement method	Indicator	Expected outcome
Flight safety incidents	Number of flight-related safety issues	Count per 1000 flights	≤ 2 incidents
Drone fail-safe activation rate	% of flights requiring fail-safe actions	% of total flights	≤ 5%
Compliance with airspace regulations	% of flights in compliance with CAA/EU rules	% of total flights in compliance	100%
Public awareness & acceptance	% of positive feedback from surveys	% approval rating	≥ 85%

Table 22. Cost and resource efficiency KPIs

KPI	Measurement method	Indicator	Expected outcome
Reduction in lifeguard workload	% decrease in manual monitoring efforts	% reduction in total patrol time	≥ 40%
Cost savings per operation	Cost comparison vs. existing services (without automation 5G4LIVES)	% reduction in operational costs	≥ 30%
Battery efficiency	Average flight duration per charge	Minutes per flight	≥ 40 min
Reduction in fuel usage	% decrease in fuel-powered patrols (boats, vehicles)	% fuel reduction	≥ 30%

5.2. Riga Use-Case Lifeguard Action Plan

5.2.1. Principles overview

Through 5G4LIVES, lifeguard operations are significantly increased by deploying drones for continuous public beach and water surveillance. Real-time aerial monitoring over 5G gives lifeguards a "live overhead" view of their area, improving situational awareness and automatic detection of risks in at-risk zones. For example, UAV surveillance can spot a swimmer in distress or a person drifting beyond safe swim zones before lifeguards on shore might notice, prompting earlier intervention.

Integrating drones into lifeguard duties is projected to improve rescue outcomes measurably. According to project estimates, search-and-rescue operations can be initiated at least 10 minutes earlier because incidents are reported/detected faster via drone feeds. Earlier detection means lifeguards begin rescue sooner, which is crucial in scenarios like drowning, where every minute counts. Moreover, having drones pinpoint a victim's last known location and track currents enables more focused deployment of rescue resources. Trials suggest that about 30% fewer personnel and equipment (boats, ATVs, etc.) are needed for search missions when drone intel is available, since ground teams can go directly to the right area. It also helps address lifeguard staffing gaps – one remote pilot can oversee the aerial patrol, effectively "adding" an extra lifeguard eye in the sky without pulling human lifeguards away from other duties.

Existing lifeguard procedures adapt substantially with drone integration. Traditionally, lifeguards patrolled swim areas by boat or on foot and occasionally flew small drones manually, which was done only sporadically due to limited battery life and the need for a trained pilot on scene. Under 5G4LIVES, routine UAV patrols beyond the buoy lines are now part of standard operations, extending surveillance to areas previously hard to watch continuously (such as beyond the designated safe swim zone). Instead of a lifeguard having to stop other work to pilot a drone, flights can be automated or controlled remotely, freeing on-site rescuers to focus on immediate rescue tasks. This means some procedural steps change: for example, when a report of a person in trouble comes in, lifeguards will coordinate a *drone launch* as part of their response (something not in legacy protocols). They will incorporate checking the drone's live video feed or communicating with the

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drone operator into their assessment of the situation. In practice, lifeguards at the beach who once relied solely on visual scanning and binoculars will now also monitor a tablet or screen streaming UAV footage, especially during peak times. In emergencies, all lifeguards can rescue while a remote pilot handles the drone, a change from earlier practice where one lifeguard might have been tied up flying a drone. Procedures for incidents like missing persons or swimmers outside buoy markers now explicitly include deploying a UAV for search support.

Overview of 5G4LIVES platform integration design – action plan in Riga Case.

Under the 5G4LIVES system in Riga, lifeguards are taking on *new tech-supported roles* and responsibilities. One major new service is UAV-assisted beach surveillance: lifeguards are now incorporated with automated drone patrols of their beach/lake area in addition to traditional watch duties. Lifeguards must be ready to interpret alerts or imagery from the drone network. For instance, if the drone's camera spots a person struggling in a rip current or an unauthorised boat, the lifeguard on duty must quickly verify and respond, to be notified from the Remote Operation Control Centre. In effect, lifeguards can also act as on-site coordinators for drone missions: they can request a drone to be dispatched to a location, pause or adjust a patrol if needed, and take appropriate action based on drone observations. Another new responsibility is basic maintenance checks of the drone station; At the same time, specialists largely handle technical upkeep, lifeguards ensure day-to-day readiness (for example, in winter they must check that the drone's roof-dock is free of ice/snow before flights). Importantly, lifeguards remain the first responders on the ground – their role is augmented, not replaced, by the UAV. They still perform rescues and first aid, but now with an added information stream and support tool from the sky.

The interaction between on-site lifeguards and remote drone operators (pilots) is designed to facilitate these new services. Drones in 5G4LIVES are operated in a network under centralised supervision – a dedicated Remote Pilot at Remote Operation Control Centre (ROCC) manages, monitors and controls the UAVs beyond visual line of sight. Lifeguards and this remote operator function as a team, communicating via the existing police radio network or dedicated 5G-connected devices. For example, suppose a lifeguard observes a swimmer disappear under water at a location outside the designated swim zone. In that case, they will immediately alert the ROCC remote pilot (over radio) and request drone support at those coordinates. The remote operator/pilot then launches the drone from its dock and guides it to the incident area, while the lifeguard moves to respond on the ground. Throughout the drone's flight, the ROCC operator updates the lifeguard ("Drone on scene in 30 seconds, it has visual on the victim") and can even relay information to other responding units. Conversely, the lifeguard on scene feeds situational info to the operator – for instance, confirming a missing person's description so the drone camera can zoom in on the right target. The 5G4LIVES platform essentially creates a real-time link between the lifeguard station and the remote operations center: the drone acts as an intermediary, sending live video to the operator and potentially directly to rugged tablets carried by lifeguards. Remote operators continuously monitor the drone network (multiple UAVs covering different zones), ready to alert lifeguards if they see an issue. For instance, the ROCC pilot might spot through the drone feed a group of swimmers being pulled out by a strong current outside the buoys and immediately radio the beach lifeguards to intervene. In such a case, the remote operator could use the drone's onboard loudspeaker to shout warnings until lifeguards reach the swimmers. This tight interaction loop ensures that no critical event goes unnoticed: the lifeguard initiates a drone mission when something is reported locally, or the ROCC operator prompts lifeguards when the drone autonomously detects an anomaly.

Technically, the 5G4LIVES integration augments lifeguard operations with a robust platform of drones, communication networks, and control systems. Each lifeguard-supervised area (e.g. Riga's Vecāķi Beach and segments of Ķīšezers Lake) is equipped with an automated drone infrastructure: drones housed in weather-proof docking stations installed on existing facilities. These docking stations keep the UAVs charged and protected, enabling rapid on-demand launches anytime. The drones carry advanced payloads –a high-resolution video camera and a thermal camera – providing both day and night vision capabilities to detect swimmers, boaters, or even people on ice in winter. The platform relies on 5G connectivity as the primary data link: each drone is outfitted with a 5G modem that maintains a real-time, high-bandwidth connection with the remote control center. This allows the remote pilot to send control commands instantly and receive live HD video and telemetry with minimal latency. It also supports network Remote ID of the UAV (broadcasting the drone's identity and location via the network) to comply with airspace regulations. The lifeguard station and

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ROCC are tied together through a central command software – a drone operations management system – that shows drone positions on a map, video feeds, and mission status. Lifeguards can interface with this system through a simplified app or interface to request a preset mission (like "scan Sector 3 of the beach") or mark a point of interest.

On the back-end, the platform integrates with the municipal police dispatch system so that emergency calls or incidents logged by lifeguards can trigger drone missions as part of the response workflow. The design emphasises safety and automation: geofenced flight corridors and predefined "UAV zones" keep the drones away from populated areas outside the mission scope and other air traffic. Many drone flights (like routine patrols) are pre-programmed missions ("Standard Scenarios") that can run autonomously, with the remote pilot simply supervising multiple drones at once. Thanks to 5G, even BVLOS flights can be confidently controlled remotely, as if the pilot were on site. The platform is also exploring AI-driven analytics – for instance, using computer vision to automatically detect a person waving for help or unsafe crowd gatherings in the camera feed. Such AI alerts would notify lifeguards and operators immediately, further speeding up response. The 5G4LIVES integration in Riga equips lifeguards with a network of "smart" drones and a dedicated remote support team, creating a seamless extension of their senses and reach through cutting-edge technology.

5.2.2. Technologies and Actors workflow

In the integrated 5G4LIVES lifeguard ecosystem, multiple actors and technologies collaborate in a coordinated workflow. The key human actors are: (1) lifeguards on site (municipal police rescuers at the beach or lake, responsible for hands-on intervention and local surveillance), (2) the remote drone pilot (an operator stationed at the ROCC who supervises and controls UAV operations), (3) the command center/dispatch (overseeing emergency communications and liaising with other services), and (4) emergency services like the Fire Fighting Service, Rescue Service, Police, Medical responders (who may be called in specific incidents). The technological actors include the drones, docking stations, 5G networks, and command & management software that orchestrates operations, flights and data. Below is a workflow that illustrates how these actors interact in different scenarios.

Routine surveillance workflow

On a typical summer day, drones conduct periodic automated patrols over the swimming area as part of routine prevention.

1. *Mission planning.* At a scheduled time in the day, the ROCC remote pilot manages automatic patrol missions via the drone control software. For example, a UAV at Vecāķi Beach might be set to fly along the 700m beachfront boundary and slightly offshore, then over dunes, on a continuous loop. The system checks 5G signal coverage and weather conditions; if all is clear, the mission is approved for launch.
2. *Pre-launch coordination.* The remote pilot notifies the on-site lifeguard (e.g. "Starting routine drone patrol now"). The lifeguard ensures the takeoff area is clear of people and gives a quick visual check of the dock (no obstructions). In high-traffic times, the lifeguard may also act as a visual observer during launch, confirming that the drone ascends without hazard and that no other aircraft are nearby.
3. *Patrol Flight.* The drone launches and follows its patrol route autonomously. It stays within a designated UAV zone and altitude (for instance, flying at ~50m along the coast) to avoid interfering with people or other airspace users. The remote pilot at the ROCC monitors the drone's telemetry and live video feed in real time, overseeing multiple parameters (position, battery, connectivity, statuses, etc) and ensuring the mission sticks to the plan. The 5G link enables continuous high-quality video streaming to the control center. During the patrol, the lifeguard can glance at a monitor (if equipped with designated device) showing the drone's feed or await updates.
4. *Detection & alert.* Suppose the drone's camera catches an anomaly – e.g. a swimmer has ventured far beyond the buoys into a dangerous area. The system's AI or the remote operator notices this. Immediately, the operator alerts the lifeguard team: "Drone has spotted a person outside the safe zone, 100m north of your station." The lifeguard on duty visually locates the person (now that they know where to look) and prepares to intervene. Meanwhile, the drone can be used to take action: the remote pilot activates the UAV's **loudspeaker** to broadcast a warning: "*You there in the green swim*

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shorts, you are outside the safe area – please return!". This often prompts the swimmer to head back towards shore on their own.

5. *Response.* If the person ignores the warning or struggles (e.g. caught in a rip current), the lifeguards respond. One lifeguard might launch a rescue boat or swim with a rescue buoy. The drone hovers over the person, continuously relaying their position. It effectively "spots" from above, helping direct the rescuer to the exact location, especially if currents have pulled the victim. Suppose a crowd forms on the beach (which can indicate panic or another incident). In that case, the drone feed helps the command center and lifeguards assess if additional police patrols are needed to maintain order. Throughout, the remote pilot may reposition the drone or zoom the camera as requested by the lifeguards (for example, to scan a wider area for any other swimmers in trouble).
6. *Resolution.* Once the swimmer is safe (brought back within the buoys or onto the lifeguard boat), the lifeguard signals "all clear." The drone might circle longer to ensure no other risks are present. Then the remote pilot commands it back to the docking station for landing and recharging. The routine patrol continues as scheduled. This preventative workflow occurs continuously, meaning many incidents are averted before they escalate. This routine operation requires minimal direct involvement from lifeguards beyond their usual patrol – the drone runs in the background, and lifeguards only step in when an alert is raised, thereby *reducing their workload* in scanning wide areas and allowing them to focus on on-ground duties.

Emergency incident workflow

The workflow ensures a swift, coordinated multi-actor response with the drone as a force multiplier in a critical emergency (for instance, a possible drowning or a missing person).

1. *Incident detection.* An emergency can be spotted by lifeguards or reported by the public. For example, a person reporting someone in the water screaming for help, or a child is noticed missing. An emergency call could be made in winter about someone who fell through ice on the lake. When such an alarm is raised, the lifeguards trigger the drone response. One lifeguard immediately contacts the ROCC operator: "Emergency at Zone 3 – deploy drone to coordinates X," giving either a GPS location or a description ("50m west of buoy line, near the red buoy").
2. *Drone deployment.* The remote pilot at the ROCC interrupts any ongoing routine flights and launches the nearest drone on an emergency mission to the incident location. Thanks to the 5G link and the system's high availability design, the drone can be in the air within seconds of the request. The ROCC operator oversees the operation process, ensuring no conflicts and that the mission is within approved parameters.
3. *Ground response.* Simultaneously, lifeguards mobilise on the ground. Following their training, all available lifeguards pivot to rescue operations when a person's life is at risk. Lifeguards fan out on foot for a missing child to search the beach and waterline. For an ice accident in winter, the lone on-duty rescuer calls in backup (additional police or fire rescue) and grabs ice rescue tools. Having the drone in the air is crucial because it provides a coordinated "eye" for all responders.
4. *Situational awareness.* As the drone proceeds to the area (flying directly to the GPS point at high speed), the remote pilot streams the video feed to the command center and can share it live with mobile devices carried by responders. The drone arrives before or simultaneously as lifeguards, since it can fly in a straight line at high speed. The camera is zoomed to locate the victim – for a drowning, it might find a person's head above water or track splashing. For a missing child, it scans the beach for anyone matching the description (bright clothing, etc.). In an ice scenario, the thermal camera might pick up the heat signature of a person against the cold background. The operator and lifeguard communicate e.g., "Drone has visual on the drowning victim, 20 meters offshore, slightly north of your position." This guides the lifeguard's boat to the exact spot, even if waves or panic make it hard to see the victim from water level.
5. *Intervention.* The drone doesn't just observe – it can actively assist. If the person in water is conscious and within earshot, the operator uses the drone's speaker: "Help is on the way, stay calm!" providing reassurance. If there are hazards (like a second person in trouble nearby or a dangerous rip current), the drone sees it and the operator warns the rescuers. Multiple agencies might be involved on the ground: the lifeguard team, additional police units, and ambulance or fire/rescue if escalated. All

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parties benefit from the drone's overhead view. For instance, if more than one person was pulled out by a current, the drone can scan a wider area to ensure no one is missed, directing backup rescuers to those people. If the incident is large-scale (say, a boat capsized with several victims), the command center could deploy multiple drones (the system has a fleet) to cover different search grids, while coordinating with lifeguards and firefighters on boats.

6. *Command center coordination.* The Operational Command Center stays in the loop for major incidents. If an incident exceeds what the lifeguards can handle – for example, a winter accident where a vehicle fell through ice requiring specialty rescue – the municipal police will escalate the call to the State Fire and Rescue Service's Command Centre. Through 5G4LIVES, any information gathered by the drone (live video, maps of the area) can be shared with those incoming responders. This is a key improvement: in the past, if lifeguards had to call in outside help, they could only describe the scene verbally; now they can *show* it via the drone's feed. The ROCC operator can relay conditions (e.g., "the drone footage shows very thin ice around the victim, approach from the east side"). This inter-agency workflow ensures a coordinated response and that everyone – lifeguards, police, firefighters, medics – have a common operating picture.
7. *Incident resolution.* Once the victim is secured (pulled from the water or ice, or the missing person found safe), attention turns to resolution. The drone may continue to hover to provide oversight (like guiding rescuers back to shore safely or watching for any new developments). After the situation is under control, the ROCC pilot will return the drone to base. All involved units then debrief. The lifeguards and remote operator log the incident details into the system. Any useful drone footage can be saved for review or training.

This workflow highlights how the integrated system handles a critical emergency: with parallel action (ground and air), constant communication, and data-driven coordination, dramatically improving the chances of a successful rescue.

Additional use cases

The 5G4LIVES lifeguard-drone workflow also covers scenarios like searching for lost persons on land and public safety surveillance:

- *Missing person on beach.* If a child is lost in the crowd (a common scenario on busy weekends), lifeguards typically spread out to search and notify police. Now, a drone can be launched to sweep the beach from above, covering far more area quickly. The workflow: lifeguards get the child's description; remote pilot sends the drone to canvass the shoreline. The camera might spot a child wandering in the dunes or along a distant part of the beach, matching the description. The operator can freeze-frame and confirm with lifeguards, then direct the nearest officer to that location. This can reunite lost children with parents much faster. It also reduces disruption – instead of halting all lifeguard duties for a prolonged search, the drone localises the search area within minutes.
- *Public order monitoring.* Lifeguards (being municipal police) are also tasked with beach public order (preventing fights, illegal vehicles on sand, etc.) The integrated workflow helps here as well. For example, during a festival at the beach, a drone patrol might notice a large crowd forming suddenly, suggesting a conflict or accident. The remote operator will zoom in and might see an altercation. They inform the lifeguards: additional patrol units can be called preemptively. The drone records video useful for evidence. If a suspect tries to flee, the drone can track them from above until police on the ground intercept – a capability already used in law enforcement that is now at the disposal of the beach patrol. All this occurs while the lifeguards maintain safety for other beachgoers, multiplying their effectiveness.

Throughout these workflows, certain technological aids ensure smooth operation. A geofenced UAV restricted zone has been established over the demo areas, authorised by Latvia's Civil Aviation Agency, so that 5G4LIVES drones can operate without unexpected intrusions by other drones. This means hobbyist drone users are kept out during operations, and if they want to fly there they must get permission – the police drone unit will vet those requests. The drones also use predefined flight plans that account for their battery limits; for instance, the large Ķīšezers lake is divided into two patrol segments because one drone battery cannot cover the whole lake in one go. When one segment is done, the drone returns to swap or recharge while a second drone covers the next, ensuring continuous coverage. The result is an orchestrated multi-actor

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operation where drones handle surveillance and searches "dull, dirty, or dangerous" aspects. At the same time, human lifeguards and police focus on direct human care and decision-making.

5.2.3. Action plan integration

Implementing drone operations into lifeguard duties under 5G4LIVES requires a clear, step-by-step action plan to ensure a smooth rollout. The integration plan in Riga involves the following key steps and considerations, described below.

Regulatory approval and framework.

First and foremost, the project team secured the necessary regulatory clearances to operate drones in these scenarios. The national aviation authority in the EU must authorise any BVLOS (beyond visual line of sight) or otherwise advanced drone operation. The Riga Municipal Police prepared a comprehensive risk assessment per Article 11 of EU Regulation 2019/947 as the basis for an operational authorisation application. This Specific Operations Risk Assessment (SORA) outlined the intended operation concept, airspace, drone specs, mitigation measures, etc., to demonstrate safety. The Civil Aviation Agency (CAA) of Latvia was engaged early, and a formal agreement was made to establish a *restricted airspace zone (R)* over Vecāķi Beach and Ķīšezers Lake exclusively for these UAV operations. The police appointed a representative to coordinate with air traffic authorities and publish the designated drone zone information (via Latvian Air Traffic/AIS). By creating this zone, ensure no conflicting air traffic and take responsibility for any other drone flights in the area (other users must request permission to fly there). In parallel, the CAA granted operational authorisation with specific conditions – for example, limits on maximum altitude, weather minimums (drones must not fly in unsafe wind or storms), and requirements for remote pilots to be certified. All these regulatory steps were completed to provide a solid legal and safety framework before live operations.

Infrastructure deployment

The next part of the action plan is deploying the technical infrastructure. This included installing at least four drone station setups (covering Vecāķi and coverage areas at Ķīšezers) as identified in the design. Each setup consists of a drone and a docking station. The docks were mounted at designated special points to give drones a safe takeoff/landing spot with good 360° visibility. Deployment also required ensuring robust 5G network coverage at those sites. Telecom deployment procedures were followed, and the signal was tested. This step was crucial because a reliable 5G link is the backbone of the control system. Teams perform special tests and flight-tests to verify strong coverage across the entire operational area, including over water. Additionally, the command & control center (located at the Municipal Police designated place) was equipped with the necessary software: a Drone Operations Management system and integration into the existing emergency response center. High-performance workstations with large displays that ran the control applications (for mission planning, live video, and management interface) were set up for the remote pilots.

Procedures and training development

A comprehensive UAS Operations Manual was developed to formalise how drones are integrated into lifeguard operations. This manual, aligned with EU standards, details organisational structure, personnel roles, operating procedures, checklists, emergency contingencies, maintenance, and training requirements. It extends the lifeguard unit's standard operating procedures, including UAV usage. Once the manual is approved (a requirement by CAA for the permit), targeted training will be implemented. Lifeguard personnel were trained and certified as needed – at minimum, each drone mission must have a certified Remote Pilot. The training program included sessions on aviation safety, 5G drone systems, and the specific software used for mission planning. It also had extensive practical components: pilots practiced on actual UAVs in manual and automated flight modes (under an instructor's supervision). They learned to manage automated missions, handle handovers between manual and autonomous control, and respond to emergencies (like communication loss or drone failsafe scenarios). Lifeguards not directly piloting were still briefed on drone operations – for instance, how to act as a visual observer, request a drone, and interpret drone signals. New checklists were introduced for tasks like pre-flight preparation, takeoff/landing safety, and post-flight equipment checks, ensuring consistent adherence to the procedure. Additionally, the team established communication protocols: which system to use for drone-related comms, codewords for certain events (to keep communications clear), and a notification procedure to local air traffic control when a flight is about to

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commence, if required. By updating the lifeguard unit's operational handbook and emergency response plans to include these elements, the groundwork was laid for everyday use of drones.

Pilot testing and demonstration

With hardware in place and staff trained, the integration proceeded to a pilot testing phase – essentially dress rehearsals for real operations. The drones were flown on non-emergency patrols to fine-tune flight routes and ensure the video feed and control systems worked as expected. The lifeguards and remote operators ran through *simulated incidents* to practice coordination: for example, a drill where a "missing swimmer" scenario is activated and the drone is deployed. These exercises allowed refinement of timing (confirming that a drone could indeed launch and reach a given point notably faster than a manual patrol), communication (making sure lifeguards and ROCC understood each other under stress), and any technical adjustments (such as camera angles or preset search patterns). The drone's live feed was displayed to observers, highlighting how the remote operator and lifeguards coordinate to save the person. Metrics like response time and resources were recorded to validate the projected 30% reduction in required search personnel thanks to the drone pinpointing the victim.

Procedure refinement and scale-up

Following the demo, feedback and lessons learned are incorporated. The action plan includes updating training manuals and operational protocols based on anything discovered during testing (for example, if the demo showed that the drone's loudspeaker wasn't heard over surf noise, they might seek a louder speaker or adjust procedures for lifeguards to use a megaphone in tandem). The ultimate goal is to transition from pilot project to daily operation. This means formalising the integrated procedures into the city's regular lifeguard operation plans, scheduling drones as part of daily duty rosters, and budgeting for maintenance and future training. It also involves ensuring ongoing compliance – renewing the operational authorisation if needed, continuing risk assessments for new scenarios, and keeping insurance up to date for the drone operations (EU regulations require liability insurance for UAV operations, so the city secures proper coverage as part of compliance. Another aspect of scaling up is community engagement: as part of 5G4LIVES, the public was informed about the new drone operations to build trust and awareness (e.g., signage at the beach explaining that a safety drone is in use, and information that the drone is there for their protection). By addressing regulatory, technical, procedural, and social factors in this multi-step action plan, Riga's lifeguard services systematically integrate drones into their workflow, aiming for a sustainable, compliant, and effective new normal for beach safety.

5G4LIVES Operations Principles

With the 5G4LIVES system operational, standard operating principles guide lifeguards and drone operators in conducting safe and effective UAV-assisted missions. These principles cover how missions are executed, how responsibilities are shared, and what procedures ensure safety for the public and the crew. Key operational guidelines include:

Pre-flight and launch protocols.

Before any drone launch, the remote pilot and involved lifeguards perform.

A pre-flight checklist is followed systematically to confirm the UAV is airworthy and all conditions are within limits. This includes verifying the drone's battery and systems status, confirming the 5G capability, and ensuring the planned flight path is free of conflicts (such as checking NOTAMs or active manned flights in the area). If the mission is planned, the operator ensures that any required notification to air traffic services is made and that the appropriate airspace restrictions are in effect (the restricted zone over the beach/lake is activated if needed, as coordinated with CAA). Weather is critical – the team checks that wind speeds, visibility, and other factors are within the drone's operating envelope and the regulatory limits. Immediately before launch, the lifeguard on site makes sure persons are at a safe distance and no one is under the drone's takeoff area. The remote pilot will only proceed when all checklist items are "green", and the lifeguard gives a local all-clear. Launch protocols dictate that the launch is aborted if any anomaly is spotted. For example, the pilot will delay takeoff if a helicopter is unexpectedly sighted nearby or the drone's self-diagnostics flag an error. When conditions are good, the drone takes off either autonomously (for a scheduled patrol) or under manual remote control (for a quick-reaction launch). Lifeguards are trained to maintain situational awareness during launch – acting as extra eyes on the takeoff, ready to shout "hold" if a curious person wanders too close or a sudden gust occurs. The mission proceeds once the drone is airborne and stable at a safe altitude.

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In-flight operation and intervention strategies

During flight, strict procedures ensure the operation remains safe and effective. The remote pilot in the ROCC continuously monitors the drone's trajectory, telemetry, and surroundings. A fundamental principle is that the pilot (or automation) will *avoid any risk of collision with other aircraft*. If a manned aircraft appears, the drone will yield right of way and, if necessary, the pilot will immediately initiate an evasive action or landing. Drones operate within the predefined UAV zone and altitude ceiling. However, if the drone strays or an unexpected obstacle (e.g., a crane or new structure) appears, the pilot is prepared to take manual control at any moment. Every flight has built-in "contingency geofences" – boundaries that trigger an alert or automatic return-to-home if crossed. There are clear intervention protocols for emergencies: if the drone malfunctions (loss of GPS, motor failure, etc.) or communication is lost, the system's Emergency Response Plan (ERP) is activated. The ERP includes automated drone responses – typically the drone will attempt to safely hover or return to base on its own if comms drop. The remote pilot also executes the ERP checklist: notifying all involved personnel of the issue, attempting reconnect procedures, and if needed, communicating with local authorities if the drone might perform an unplanned landing. The lifeguards are instructed on what to do if a drone emergency occurs – generally, maintain visual contact, keep people away from underneath the drone's path, and be prepared to secure the drone if it lands nearby. On the operational side, the principle is to maximise the drone's assistance during a flight. That means using its capabilities fully – zooming the camera, switching to thermal imaging at night or in low visibility, using the loudspeaker when appropriate, and even leveraging data like the drone's GPS coordinates to mark incident locations for other responders. Every drone flight is documented: the systems log the flight details and any notable events or deviations.

Workload allocation and team roles

Effective use of drones necessitates clear division of labor so that humans and machines each do what they are best at. Under the integrated operations, lifeguards on the beach focus on direct human interaction and rescue, while the remote drone operator focuses on piloting and surveillance. In practice, this means once a drone is airborne, the on-site lifeguards do not need to micromanage it – they trust the ROCC pilot to handle the flight and sensor operation. The lifeguards prepare rescue gear, keep the public safe, and perform rescue or first aid. The remote pilot, meanwhile, has the sole task of managing the UAV; they are not involved in physically rescuing people and thus can devote full attention to the aerial perspective. This segregation of duties is crucial in emergencies: previously, if a lifeguard had to operate a drone and help a drowning victim, it stretched their capacity dangerously thin. Now, the workload is distributed – technology handles observation and relays info, freeing lifeguards to act on that info. A principle of operation is that no lifeguard should multitask beyond safe limits. For example, suppose only two lifeguards are on duty and both are needed to perform CPR on a pulled-out drowning victim. In that case, neither will break away to watch the drone feed – that job will be entirely on the remote operator and any additional support at the command center. The system is designed so that the drone can function with minimal input during those critical moments (it might circle autonomously over the scene, continuing to record and provide an overhead view to remote supervisors). In routine times, one lifeguard may liaise with the drone operator – acting as a local "mission coordinator" – while their colleagues continue patrolling the beach. This lifeguard coordinator might carry a tablet showing the drone's video, ready to direct ground units as needed. Remote operators themselves may handle multiple drones (for instance, one ROCC pilot might supervise the two drones operating over Ķīšezers segments concurrently). Still, procedures ensure they do so only within manageable limits. Generally, a single operator can oversee 2–3 autonomous patrols but will only actively control one drone at a time if manual intervention is needed. If a high-stakes incident occurs, the operator will focus on that drone and let other patrol missions go into holding patterns or return to base. Teamwork extends to emergency services: if firefighters or paramedics join the operation, one police officer (or lifeguard) will be designated to communicate with them so that instructions and information (including what the drone observes) flow through a clear channel. Everyone involved knows their role and responsibilities as defined in the operation manual, preventing confusion. These allocations ensure that human resources are used efficiently – no one is idle and overloaded – and the technology is used to its fullest to back them up.

Command and control coordination.

Maintaining clear command and control is an operational principle especially when blending remote and on-site teams. The operation center (ROCC) serves as the primary point of monitoring and control for the drones, but lifeguard station officers have authority over the immediate safety operations. In effect, there is a unity of command: the incident commander (often the senior lifeguard/police officer on scene) calls the shots for the rescue. At the same time, the remote pilot controls the drone in a manner that best supports that mission. Continuous communication ties these together. To facilitate this, standard communication protocols are used – e.g., using plain language or predefined signals to indicate what is needed. The ROCC pilot might say "Drone will hold position," to which the lifeguard incident commander might reply "confirm," or ask for specific maneuvers like "Perform a wider search to the east." Suppose disagreements or uncertainties arise (like the pilot sees a risk the on-site team cannot, or vice versa). In that case, there is a principle of *safety first*: the more conservative action is taken while clarification happens. For example, if the remote pilot feels the drone should gain altitude to avoid a flock of birds even though that might reduce video detail, they will do so and inform the team. Regular briefings are instituted as part of coordination. At the start of each shift or day, the lifeguard team and the drone operators can perform a short briefing (often remotely via call) to review the day's plan: known events (e.g., a regatta in the lake that day), weather forecast, any equipment issues, and assign who is the primary contact at the beach for drone matters. Likewise, after significant missions, a debrief occurs to capture what went well or what can be improved. This tight coordination loop ensures that the drone integration operates as a coherent extension of the lifeguard service, not a separate silo.

Training and proficiency maintenance

Operational excellence is supported by continuous training. All personnel in the UAV-assisted lifeguard operations undergo initial and periodic training specific to their roles. Remote pilots, as noted, achieve certification and then receive scenario-based training for beach rescue support. Lifeguards receive technology orientation – for example, learning how to interpret thermal images (so they can understand what the drone pilot is describing in a night operation) and practicing directing a drone via radio. The operations manual mandates annual refresher training for drone pilots, including emergency procedure drills. Suppose a pilot or even an assisting observer has not participated in a drone operation for over 6 months. In that case, they must re-demonstrate their skills according to a subset of initial training steps. This ensures no degradation in skills due to inactivity. Lifeguards also integrate drone scenarios into their regular exercises – for instance, during pre-season lifeguard training, they might have a module where a drone is used so that everyone gets comfortable with the dynamics. The command center staff (like dispatchers who might interface with video feeds) receive training to use any new software tools and to understand the capabilities and limitations of the drones, so they dispatch resources appropriately. The project emphasises a *learning culture*: incidents or near-misses are reported and analysed (there's an incident reporting system per the safety management section of the manual) to update training materials and prevent reoccurrence. The team ensures the integrated operations remain sharp and reliable by maintaining high proficiency and knowledge – from remote pilot technical skills to lifeguard decision-making aided by drone data.

Safety and compliance measures

Finally, all integrated operations strictly adhere to safety regulations and best practices, embedding compliance into everyday routines. The drones and their use comply with EU aviation rules and local laws. For instance, each drone carries a Remote ID transmitter (network-based, as mentioned) to broadcast its identity per EU requirements for unmanned aircraft, and the remote pilot ensures this is active and updated before flight. The operations abide by the constraints of the issued operational authorisation – such as not exceeding the approved altitude (e.g., 120 meters) and staying within the geographic bounds. If the authorisation or law imposes a time-of-day limit (for example, maybe no night flying without special permission), the team will not launch at night unless that has been secured. Risk mitigation measures identified in the risk assessment are rigorously followed. For example, if the SORA analysis determined a certain standoff distance from crowds must be maintained, the drone's flight plans and live geofence are configured never to violate that buffer. The remote pilot and lifeguards are empowered to abort any drone operation if they perceive an unforeseen risk to people or property – no mission is so important as to compromise safety. Compliance also extends to data protection: since the drones capture video of public areas, the municipal police follow GDPR and local privacy rules in handling the footage. Video is transmitted on secure encrypted links; recordings are stored securely and only retained as long as necessary for incident documentation or project analysis. Public announcements and signage ensure that beach visitors know the surveillance in place, fulfilling transparency requirements. Another compliance aspect is insurance and liability coverage – the city has insured the drone operations for

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third-party liability (mandated for operations in specific categories in Europe), protecting operators and the public in the unlikely event of an accident. Regular maintenance of the drones and docks is scheduled per manufacturer recommendations and documented, to prevent technical failures (the manual's maintenance section covers pre- and post-flight inspections, and the involvement of certified technicians for any repairs). Environmental conditions are also respected; for example, if operations could disturb protected wildlife (since Vecāķi is near a nature park), the team coordinates with environmental authorities and possibly limits drone activity during sensitive periods – this aligns with the project's goal of protecting lives *and* the environment.

Conclusions

This section describes the project's technological advancements into actionable changes and targets for lifeguard operations. A primary decision was to define a set of Key Performance Indicators (KPIs) to quantitatively measure the improvements brought by 5G4LIVES. By doing so, the project commits to specific performance goals (e.g., how much faster responses should be, how much area is covered by drone patrols, etc.), providing clear criteria for success. Another key decision was to formalise a workflow integration plan, providing the standard operating procedures (SOPs) for lifeguards to include drone and platform use at every appropriate step. The plan also had to account for coordination with existing emergency services (police, medics), meaning roles and communication channels were decided in advance. For example, a decision could be that the remote drone pilot is now a standard role during beach operations, distinct from traditional lifeguard roles, ensuring someone is always at the control console when drones are flying. The project also decided on a continuous improvement approach: KPIs might be revised after analysing demonstration results, meaning the action plan is adaptive. This is important because it acknowledges that initial targets might change once real data comes in – a decision to remain flexible and data-driven. Lastly, it was decided to align some of the action plan elements with best practices from related EU projects and to factor in cost and environmental considerations (like fuel savings from using drones vs patrol boats) into the plan, so that the new lifeguard model is not only effective but also sustainable and justifiable in the long run. One critical metric is the UAV deployment time, defined as the time from a distress signal to the drone being launched. The target was to have a drone airborne in ≤ 40 seconds after an alert, which is a dramatic improvement over manual response that might take several minutes to get a lifeguard to the scene. Another is UAV response time (time from launch to reaching the incident), which wasn't given a fixed target in the document, but the goal is clearly to minimise it. By combining these metrics, the aim is that an eye in the sky is over an incident much faster than before. Regarding overall lifeguard reaction, lifeguard response acceleration was targeted at ≥ 30% faster than baseline (pre-drone) response times. This could mean that if it used to take 10 minutes to reach a victim, it should now take 7 minutes or less, thanks to drone support. A KPI for operational coverage expansion aimed for about +50% of the area covered compared to traditional lifeguard patrols. In practice, this means parts of the beach or lake that lifeguards rarely watch (due to limited personnel) will now be regularly monitored by drones, closing coverage gaps. Detection accuracy is another metric – the plan expects the drones (with their cameras and AI analytics) to correctly identify at least 90% of incidents (e.g., spotting a person in trouble in the water).

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CONCLUSIONS

The 5G4LIVES project has successfully defined the integration of 5G networks, UAVs, and automated emergency response systems into a scalable, efficient, and technologically advanced platform for lifeguard operations and disaster response. The structured approach has refined technical specifications, developed operational methodologies, and addressed regulatory compliance to ensure safe and effective UAV-assisted emergency response. Specific 5G-powered UAV solutions, network technical solutions, and operational workflows have achieved significant technical progress. The Riga and Turin use-cases validated customised 5G network deployments, ensuring uninterrupted UAV communication. The n78 frequency band in Riga was chosen to support Standalone (SA) and Non-Standalone (NSA) 5G connectivity, ensuring high-speed, low-latency drone control. The Turin case used a movable 5G base station to demonstrate how portable networks can extend coverage in remote locations. Network slicing and quality of service prioritisation have been identified as future enhancements to improve UAV operational reliability.

The selection of UAV platforms, which refers to specific operational needs, was a key milestone. The project successfully defined detailed technical, operational and performance specifications for multirotor drones with docking stations in Riga, ensuring automated operations, minimising manual intervention and maximising uptime. Compliance with EASA regulations was maintained, with UAVs classified under C2 and C6 categories, enabling BVLOS flights and long-range missions under controlled conditions. The lifeguard management platform is designed for drone mission planning, live video streaming, data analytics, and remote piloting and is integrated into a multifunctional interface. The system enables real-time UAV control, allowing lifeguards and emergency responders to monitor incidents, analyse sensor data, and issue automated alerts. The integration of VMS merges UAV feeds with municipal surveillance systems, ensuring improved situational awareness and cross-agency coordination.

The operational workflow developed under 5G4LIVES ensures compliance with European aviation safety standards, particularly for BVLOS operations. Adopting standardised risk assessment methodologies (SORA, STS-02) provides alignment with U-space principles, ensuring possible future integration into national aviation frameworks. Developing a risk-aware situational awareness tool enhances flight path planning, reducing operational risks. The environmental impact and sustainability assessment identified opportunities for future renewable energy sources in powering 5G infrastructure and UAV operations, with potential transitions to hydrogen fuel cells and battery lifecycle management. UAVs significantly reduce the carbon footprint compared to conventional rescue vehicles such as helicopters and boats, reinforcing the sustainability aspect of the system. The 5G4LIVES project established tactical Key Performance Indicators to measure the efficiency of UAV-assisted lifeguard operations. The lifeguard action plan defined decision-making structure, communication flows, and training aspects through structured workflow integration, ensuring UAVs enhance rather than replace human decision-making. The modular and scalable system design ensures adaptability for deployment beyond the initial pilot locations. The findings and methodologies presented in this deliverable can serve as the foundation for a scalable framework applicable across the EU, offering a replicable model for UAV-assisted emergency response in coastal, urban, and remote environments.

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