Project: ARtificial intelligence platform to prevent Climate change natural hazArds (ARCA):

Appendix to the Deliverables (Ver. 1.1):

Del. 1.2.1- Report on the deployment of the drones and video cameras

Del. 1.4.1- Report on the test and validation of the infrastructure

Partner: MECOnet

Test places: Podgorica, MECOnet premises and Podgorica's hills (Dajbabska Gora)

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ARCA MobileWatchStation

Mobile remote monitoring platform for continuous surveillance and early wildfire detection – video cameras aspect

Abstract:

This Appendix presents the design, implementation, and preliminary validation of the ARCA MobileWatchStation, a self-powered autonomous platform for continuous environmental monitoring and early wildfire detection. The system integrates a visible-spectrum PTZ camera, a thermal camera, environmental sensors, photovoltaic power supply, and 4G communication into a portable monitoring unit connected to the ARCA/MECOnet cloud platform. The principle of operation, system architecture, and communication infrastructure are described, together with the developed web-based monitoring interface. Laboratory experiments using a simulated fire source and preliminary field deployment under real outdoor conditions were conducted to verify system integration, autonomous operation, remote monitoring capabilities, and imaging performance. The results demonstrate the operational readiness of the prototype and provide a foundation for the next

development phase, which will focus on AI-assisted wildfire detection and quantitative performance evaluation through controlled fire experiments.

1. Principle of Operation

The proposed system is a self-powered remote monitoring platform intended for continuous surveillance and early wildfire detection. It integrates a visible-spectrum PTZ camera, a thermal camera, environmental sensors, a communication gateway, and an autonomous power supply into a single field-deployable and wearable unit. The overall system architecture is shown in Figure 1.

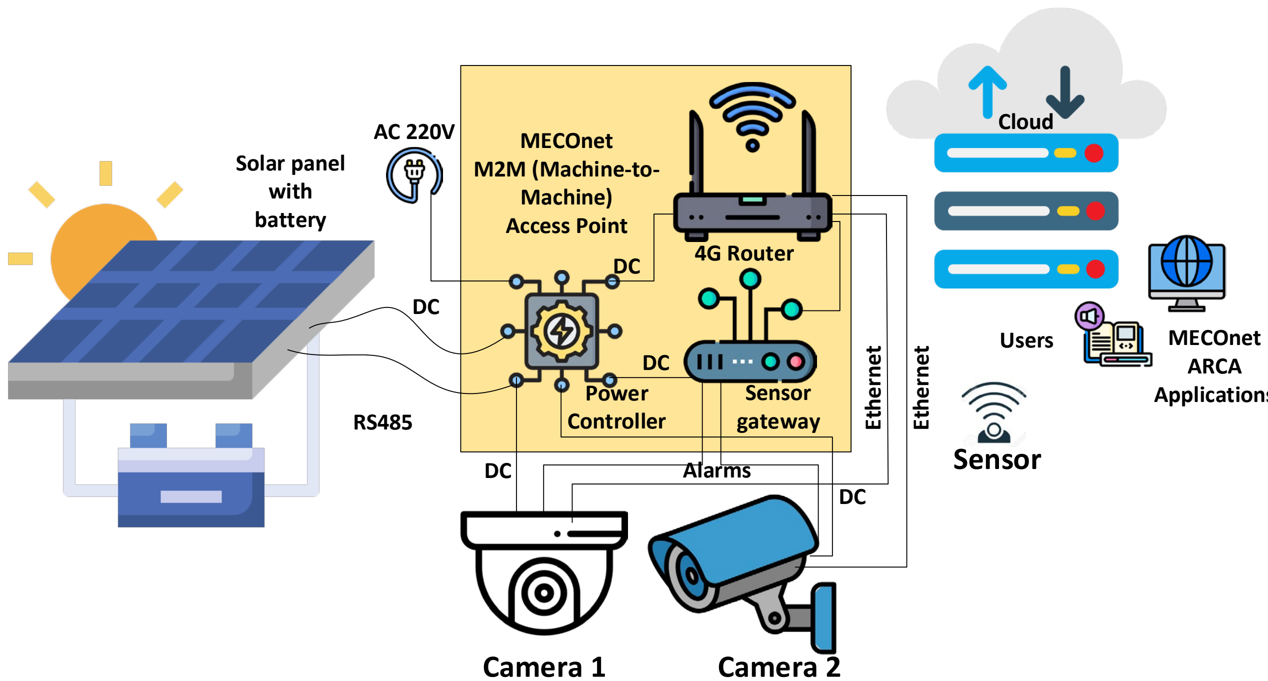

Figure 1. Architecture of the ARCA MobileWatchStation.

The system is powered by a photovoltaic (PV) solar panel coupled with a rechargeable battery, enabling continuous operation at remote locations without permanent electrical infrastructure. Where available, a 220 V AC power source may also be connected as an auxiliary power supply or for battery charging. A power controller manages energy distribution and battery charging to ensure uninterrupted operation of all connected devices.

The monitoring subsystem consists of two complementary cameras. **Camera 1** is a high-resolution visible-spectrum PTZ (Pan–Tilt–Zoom) camera that provides detailed optical surveillance of the monitored area. Remote pan, tilt, and zoom functions allow operators to inspect specific locations and verify detected events. **Camera 2** is a thermal imaging camera that continuously observes the scene in the infrared spectrum, enabling the detection of abnormal temperature distributions that may indicate the presence of a fire. Thermal imaging supports continuous monitoring during both daytime and nighttime operation and is less affected by reduced visibility caused by smoke or haze.

Environmental sensors connected through the sensor gateway provide additional measurements, including ambient temperature, humidity, wind conditions, or other environmental parameters, depending on the installed sensor configuration. Sensor gateway also can accept alarm signals from cameras and inform user of fire or movement events. These measurements complement the camera observations and may be used to improve fire risk assessment and event validation.

All system components communicate through an Ethernet network connected to a 4G router, which provides secure communication with the MECOnet cloud platform. The communication infrastructure enables transmission of live video streams, thermal imagery, sensor measurements, system status information, and alarm notifications to remote users. Operators can access the system through a web-based interface to observe live camera feeds, control the PTZ camera, review thermal images, and monitor sensor data in real time.

The fire detection process is based on continuous analysis of the visible and thermal image streams. When a potential fire is detected by the image processing algorithms, an alarm event is generated and transmitted to the remote monitoring platform. The availability of both visible and thermal imagery enables visual confirmation of detected events and contributes to reducing false alarms. Sensor measurements can be used as supplementary information for alarm verification and situational awareness.

The proposed architecture provides an autonomous mobile platform for continuous environmental monitoring and early wildfire detection or general surveillance. By combining renewable power supply, wireless communication, optical and thermal imaging, and environmental sensing, the system is suitable for deployment in remote forested areas and other locations requiring continuous unattended surveillance.

2. Preliminary testing

2.1 Training field testing

Before conducting field deployment, the ARCA MobileWatchStation prototype was evaluated under controlled outdoor conditions at the MECOnet training facility. The objective of these preliminary experiments was to verify the integration of the hardware and software components, validate the communication between the cameras and the MECOnet platform, and assess the capability of the visible and thermal cameras to detect a controlled fire source. The experimental setup is illustrated in Figure 2, where the Mobile WatchTower prototype observes a torch used as a simulated fire source.

A portable petrol-based torch was used to simulate an open flame and smoke at different distances from the monitoring system. The tests were designed to verify the response of both the visible-spectrum PTZ camera and the thermal camera under controlled conditions before conducting field experiments. Images and thermal data were transmitted through the 4G communication network to the MECOnet web application, where they were observed in real time.

The first experiment was performed with the torch positioned approximately 10 m from the monitoring platform. The visible-spectrum PTZ camera successfully captured the simulated fire source, as shown in Figure 3, providing clear visual confirmation of the flame under night-time conditions.

Simultaneously, the thermal camera detected the heat source and clearly distinguished the flame from the surrounding environment. Figure 4 presents the thermal image together with the corresponding visible-spectrum image acquired by Camera 2 at the same distance. The results demonstrate the complementary information provided by the thermal and optical sensors and confirm the correct operation of both imaging channels.

To evaluate the influence of distance on thermal detection, an additional experiment was performed with the simulated fire located approximately 50 m from the monitoring platform. As illustrated in Figure 5, the thermal camera continued to detect the flame, demonstrating its capability to identify localized heat sources at increased observation distances under controlled outdoor conditions.

The training field experiments verified the successful operation of the imaging subsystem, communication infrastructure, and MECOnet visualization platform. The tests confirmed that both cameras were able to acquire and transmit images of the simulated fire source, providing the basis for subsequent field validation under realistic wildfire monitoring conditions.

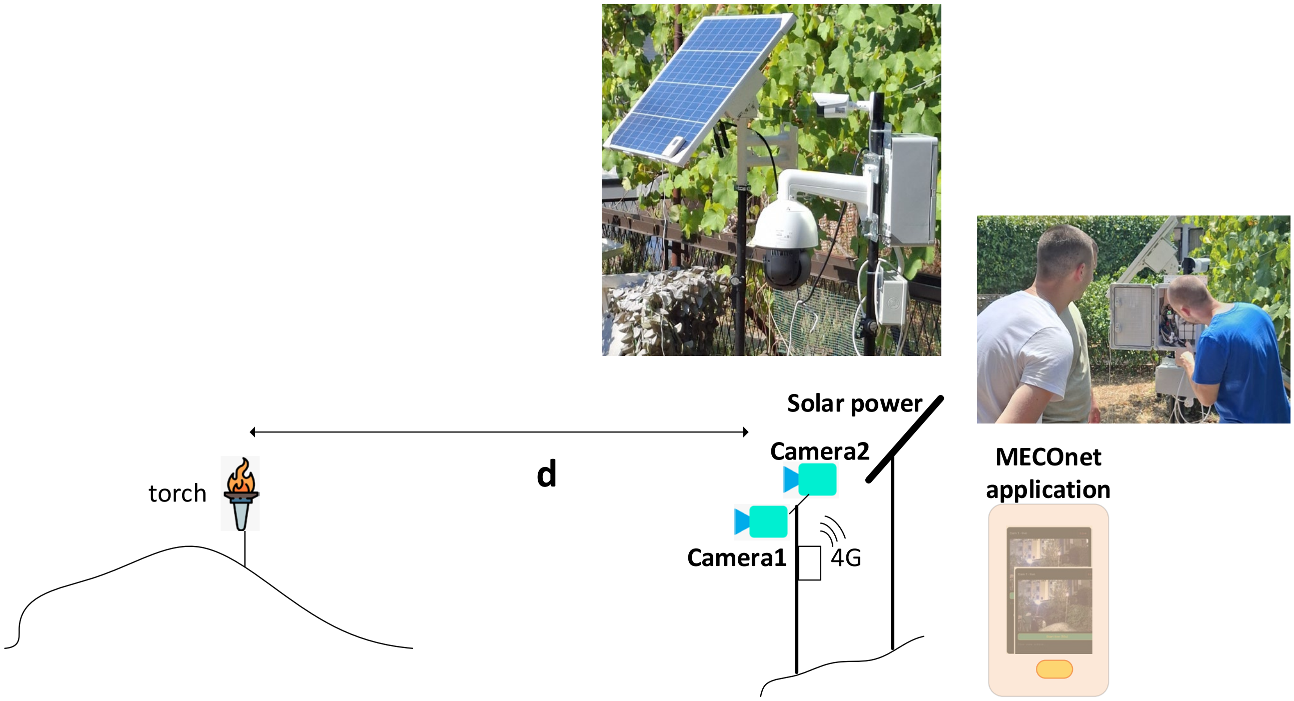

Figure 2. Experimental setup of the ARCA MobileWatchStation during controlled outdoor testing with a simulated fire source.

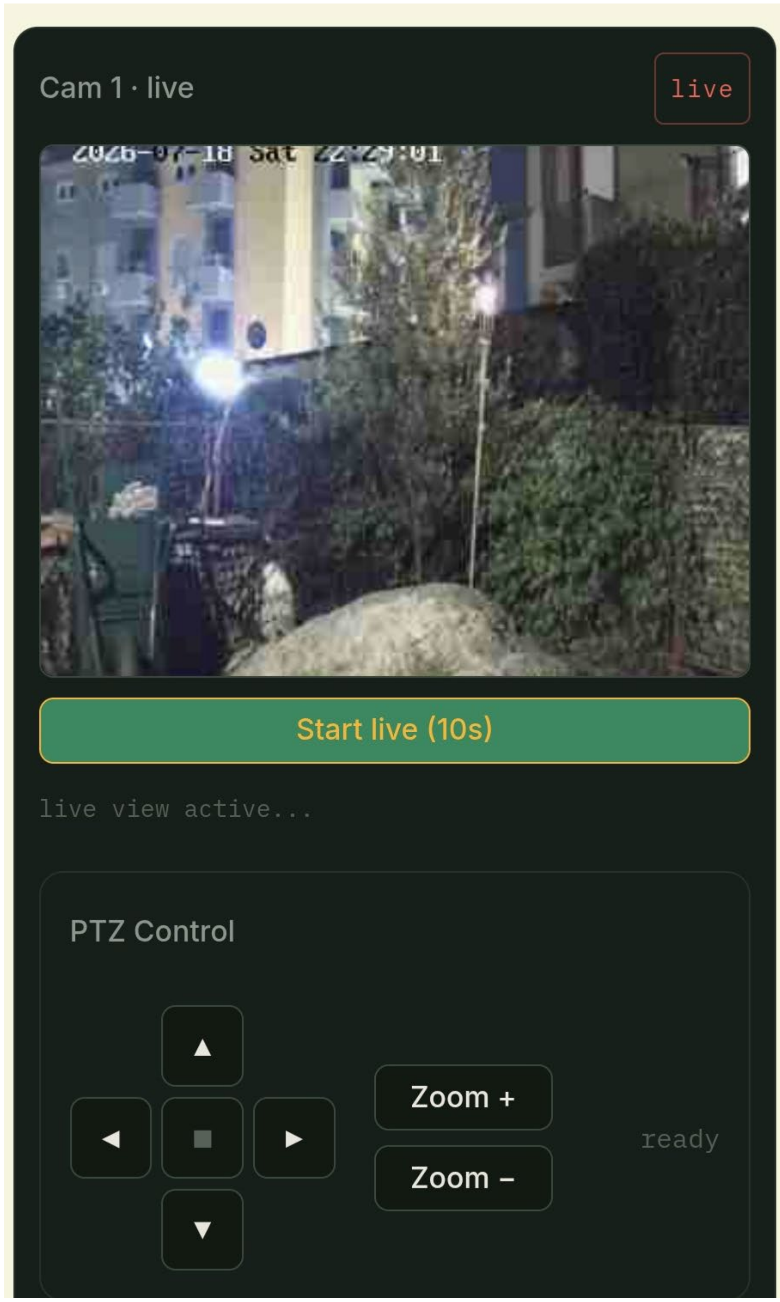

Figure 3. Visible-spectrum image acquired by the PTZ camera during the 10 m flame detection test.

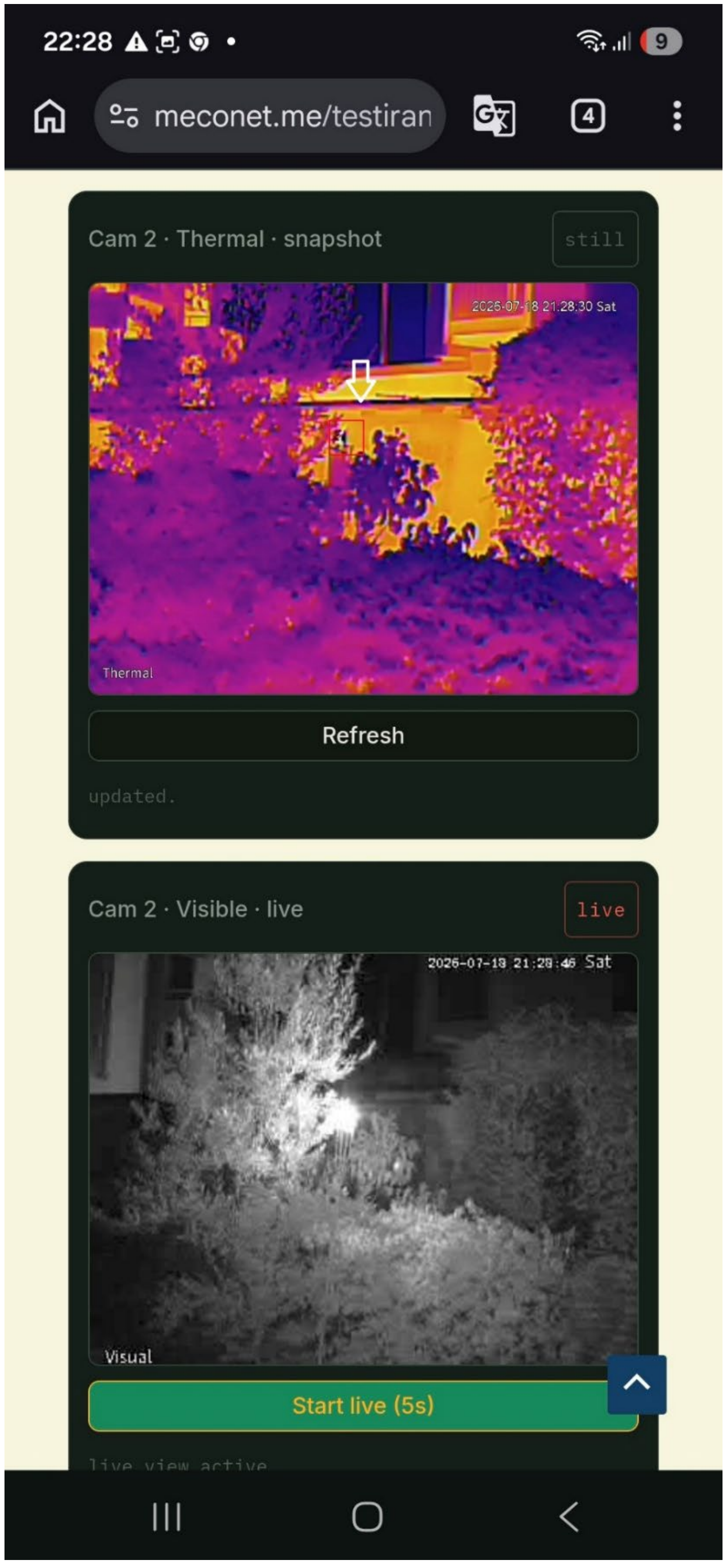
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Figure 4. Thermal (top) and visible-spectrum (bottom) images acquired by Camera 2 during the 10 m flame detection test.

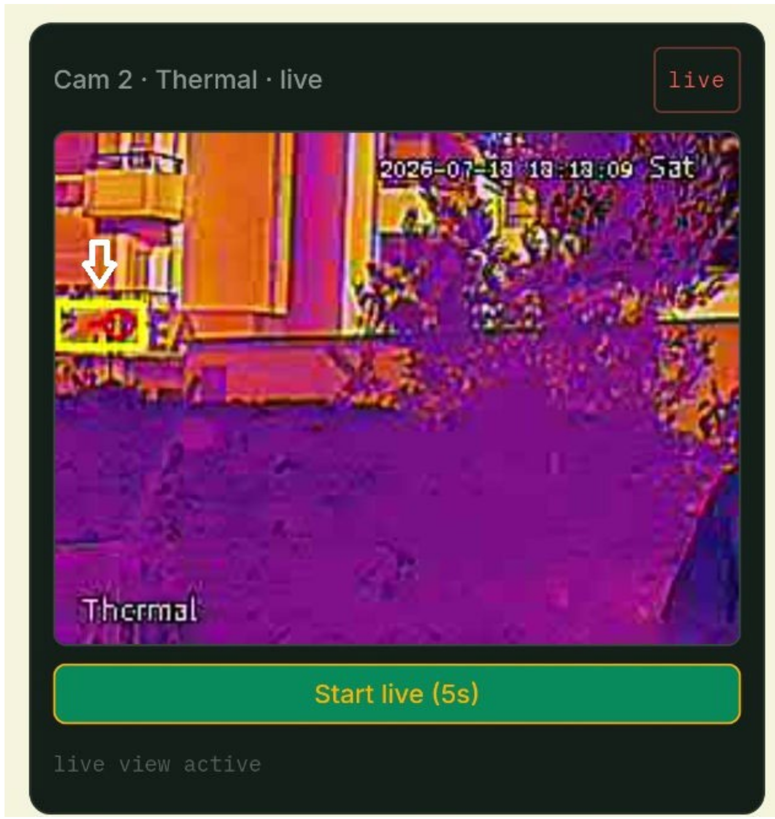


Figure 5. *Thermal image acquired by Camera 2 during the 50 m flame detection test.*

2.2 Real field testing

To evaluate the operational readiness of the proposed wildfire monitoring platform, a preliminary field deployment was conducted at Dajbabska Gora, near Podgorica, Montenegro, location 42.42052289206748, 19.23526918284226. The selected site provides an elevated observation point with an unobstructed view of forested areas and the surrounding landscape, allowing assessment of the monitoring capabilities under realistic outdoor conditions. The installed prototype and the monitored environment are shown in Figures 6–.

The prototype consisted of a photovoltaic power supply, battery storage, power controller, visible-spectrum PTZ camera, thermal camera, environmental sensors, Ethernet communication network, and a 4G router connected to the MECOnet cloud platform. During the testing period, the autonomous power system successfully supplied all equipment, while the communication subsystem maintained continuous connectivity between the remote installation and the cloud platform. These tests confirmed the correct integration of the power management and communication infrastructure under field conditions.

Prior to operational testing, the cameras were aligned using characteristic landmarks within the monitored area. A map indicating the selected reference locations is presented in Figure 9. These landmarks were subsequently used to verify the field of view, camera orientation, and image quality during remote operation.

The visible-spectrum PTZ camera was evaluated through the MECOnet web application by testing live video transmission together with remote pan, tilt, and zoom functionality. The camera provided high-resolution images of the monitored area, allowing detailed inspection of distant objects and terrain features. An example of the acquired visible-spectrum image is presented in Figure 10, where characteristic reference points are clearly visible and can be used for camera calibration and scene verification.

The thermal camera was operated simultaneously with the PTZ camera, providing continuous infrared monitoring of the same scene. Thermal imagery enabled visualization of temperature distributions across the observed area and demonstrated the capability for day and night surveillance. An example of the thermal image is shown in Figure 11. In addition, the visible-spectrum channel integrated into the thermal camera was verified, allowing direct comparison between optical and thermal observations of the monitored scene, as illustrated in Figure 12.

Throughout the field deployment, live video streams, thermal images, environmental sensor data, and system status information were successfully transmitted through the Ethernet network and 4G communication link to the MECOnet cloud platform. Remote operators were able to access the web interface, observe live camera feeds, control the PTZ camera, and monitor the operational status of the complete system without requiring physical access to the installation site.

The preliminary testing demonstrated the successful integration of all major hardware and software components into a functional autonomous monitoring platform. The activities confirmed the correct operation of the renewable power supply, communication infrastructure, cloud connectivity, remote visualization, camera control, and environmental monitoring under realistic outdoor conditions. At this stage, the testing focused on validating system integration and operational readiness. Quantitative evaluation of wildfire detection performance, including detection range, detection time, localization accuracy, false alarm rate, and system availability, will be carried out during the next phase of the project using controlled fire experiments.

To further evaluate the imaging capabilities of the Mobile WatchTower, additional observations were performed over the urban area surrounding the test site. The visible and thermal channels of Camera 2 were used simultaneously to monitor the same scene, allowing direct comparison between optical and infrared observations. As shown in Figure 13, the thermal image clearly highlights temperature differences between buildings, vegetation, roads, and other objects, while the visible image provides detailed visual context for scene interpretation. The complementary information obtained from the two imaging modalities supports improved situational awareness and facilitates verification of potential fire events.

The long-range observation capability of the visible-spectrum PTZ camera was also verified by evaluating its optical zoom functionality. Figure 14 demonstrates the ability of Camera 1 to acquire detailed images of distant objects while maintaining sufficient image quality for visual inspection. This capability is particularly important for wildfire monitoring, where potential fire sources detected by the thermal camera can be further investigated and verified using high-resolution optical imagery.

Figure 6. Prototype installation at the Dajbabska Gora test site near Podgorica, Montenegro. The system consists of a photovoltaic power supply, communication equipment, PTZ camera, and thermal camera.

Figure 7. View of the monitored area from the Dajbabska Gora installation site overlooking Podgorica and the surrounding forested terrain.

Figure 8. Representative scene observed by the monitoring system during field deployment.

Figure 9. Map of the monitored area showing the installation site and characteristic reference points used during camera alignment and field testing. 42.42052289206748, 19.23526918284226 is position of the ARCA MobileWatchStation.

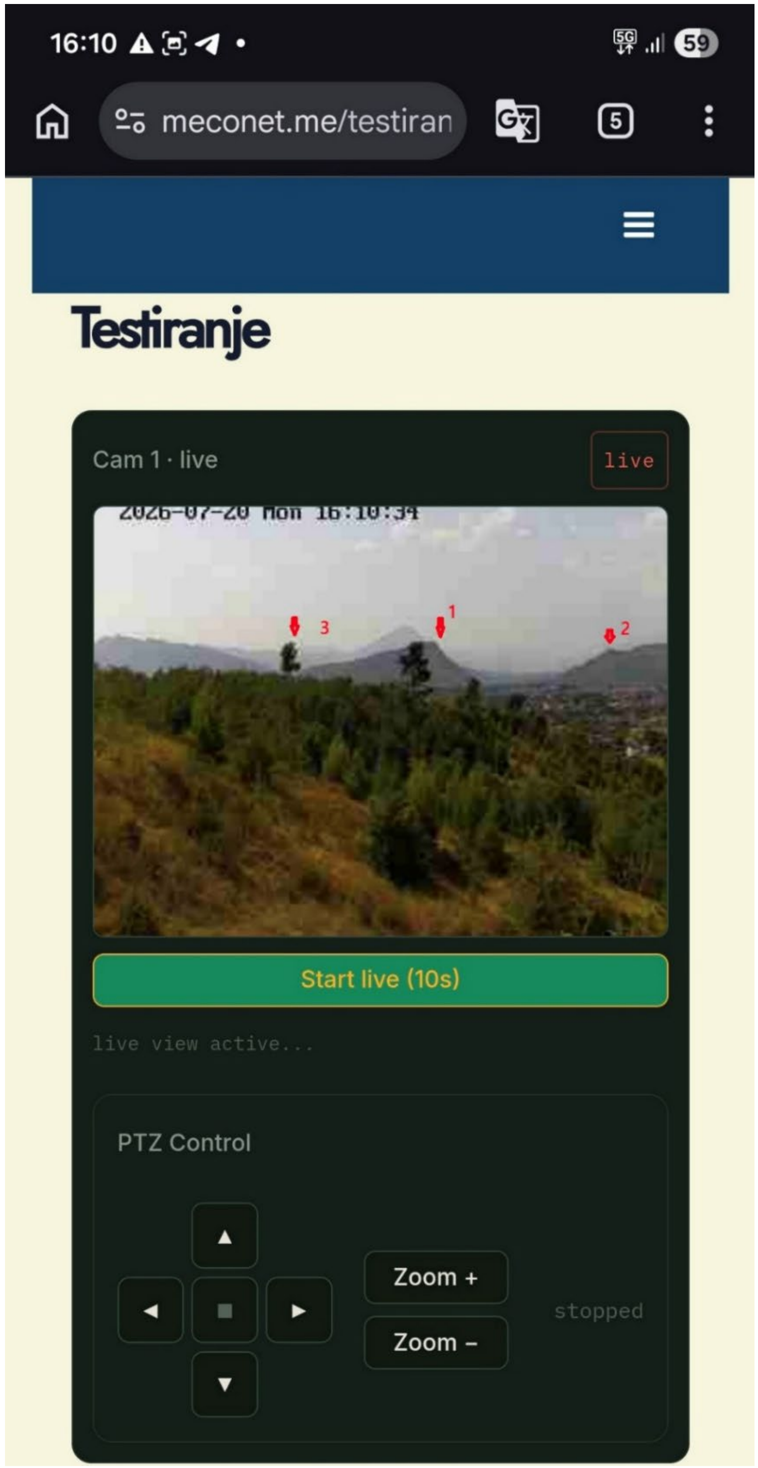


Figure 10. Visible-spectrum image acquired by the PTZ camera through the MECOnet web application. Numbered markers indicate characteristic landmarks used as reference points during system verification.

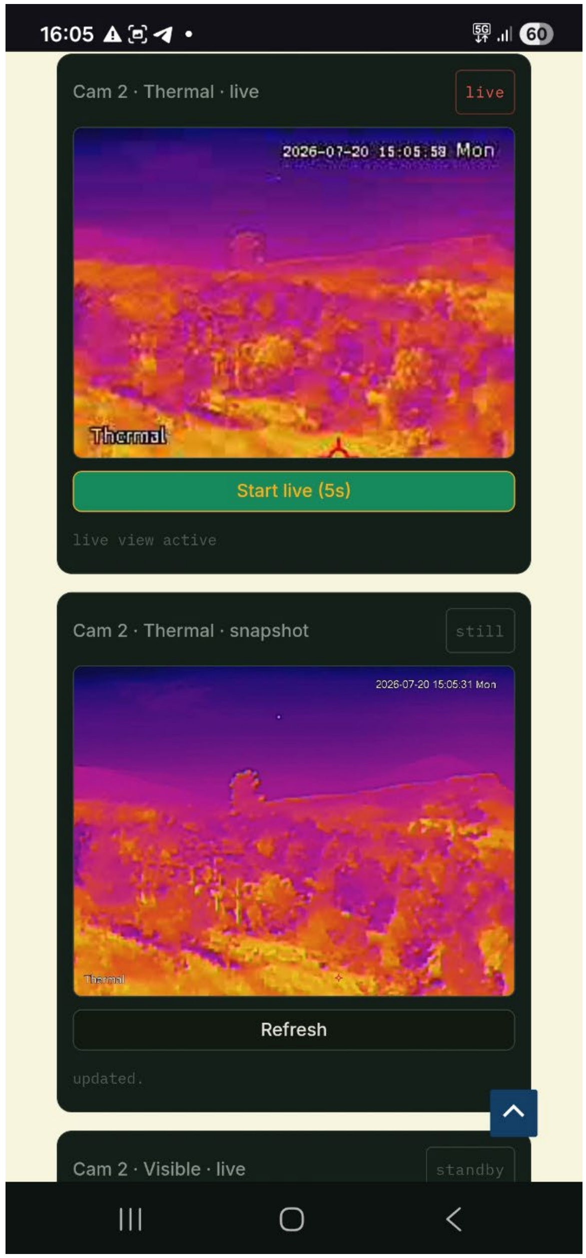


Figure 11. Thermal image acquired by Camera 2 through the MECOnet web application, illustrating infrared monitoring of the observed scene.

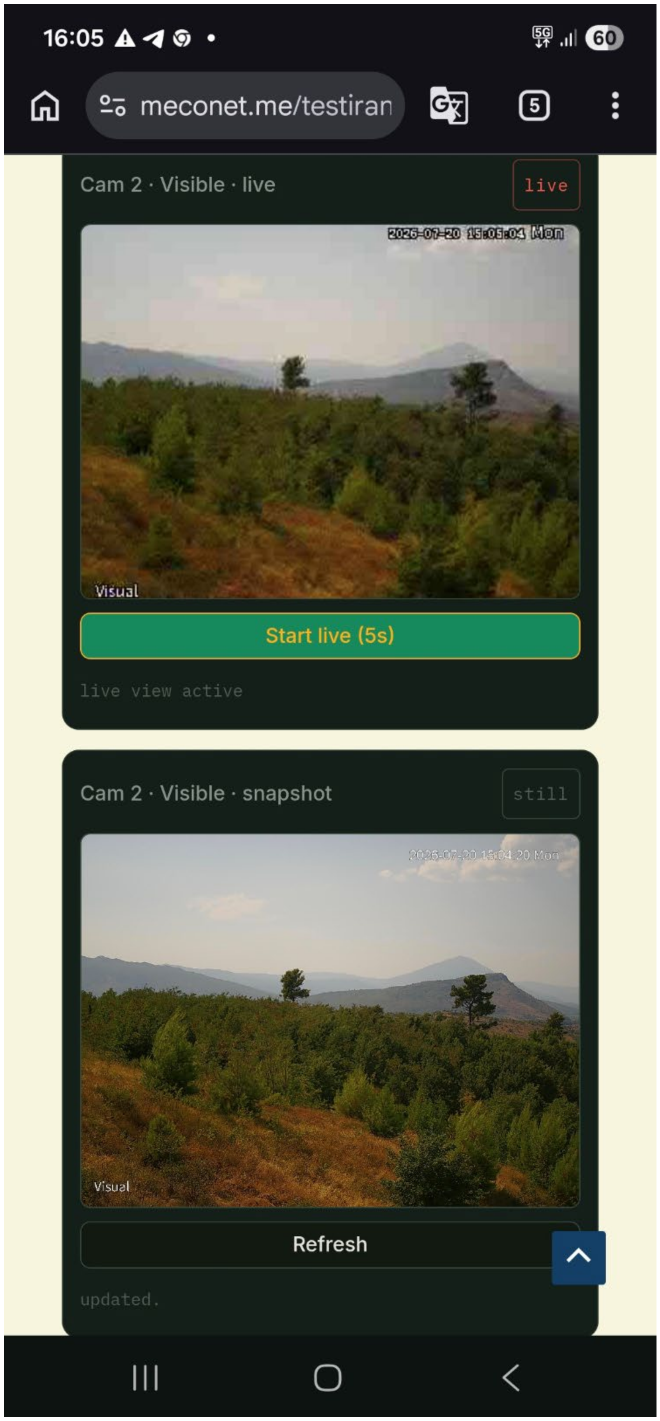


Figure 12. Visible-spectrum image acquired by Camera 2 through the MECOnet web application for comparison with the corresponding thermal image.

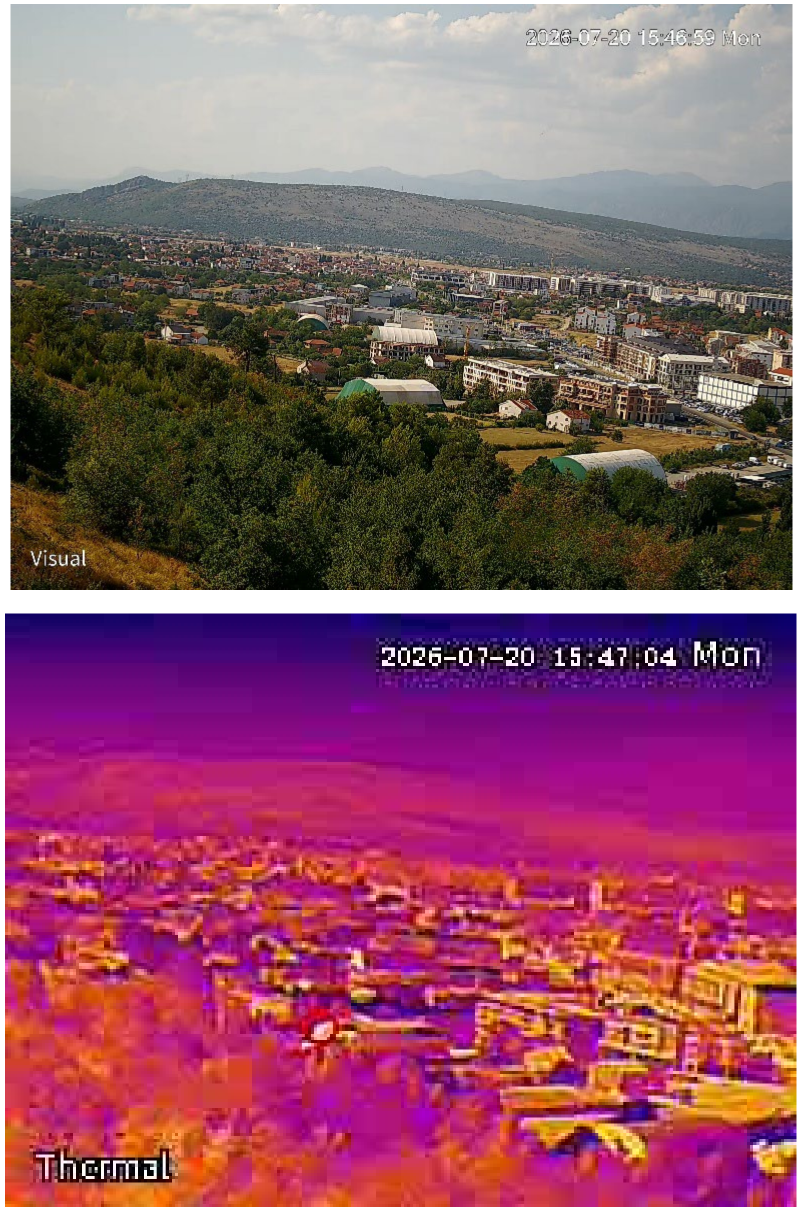
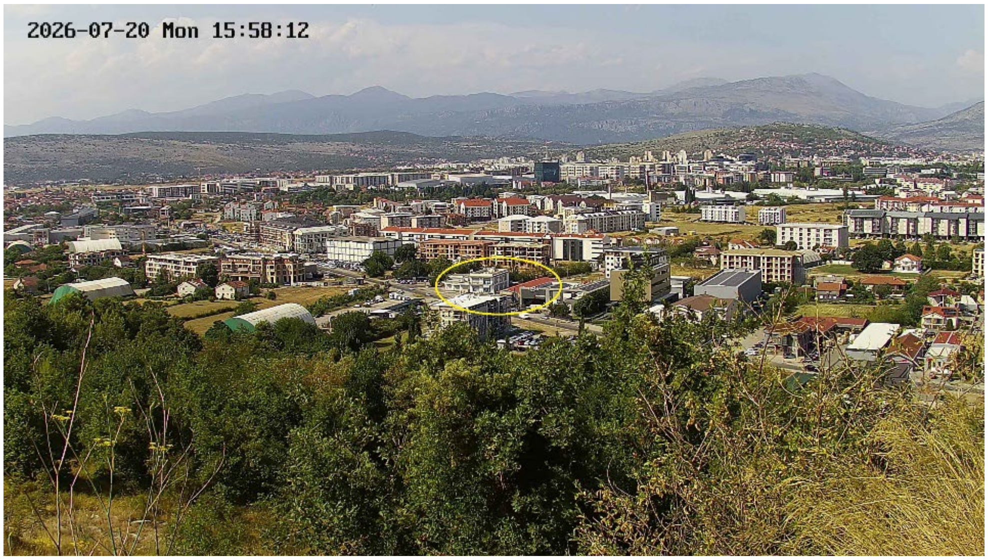


Figure 13. Simultaneous visible-spectrum (top) and thermal (bottom) images acquired by Camera 2, demonstrating complementary observation of the monitored urban area and highlighting temperature variations within the scene.



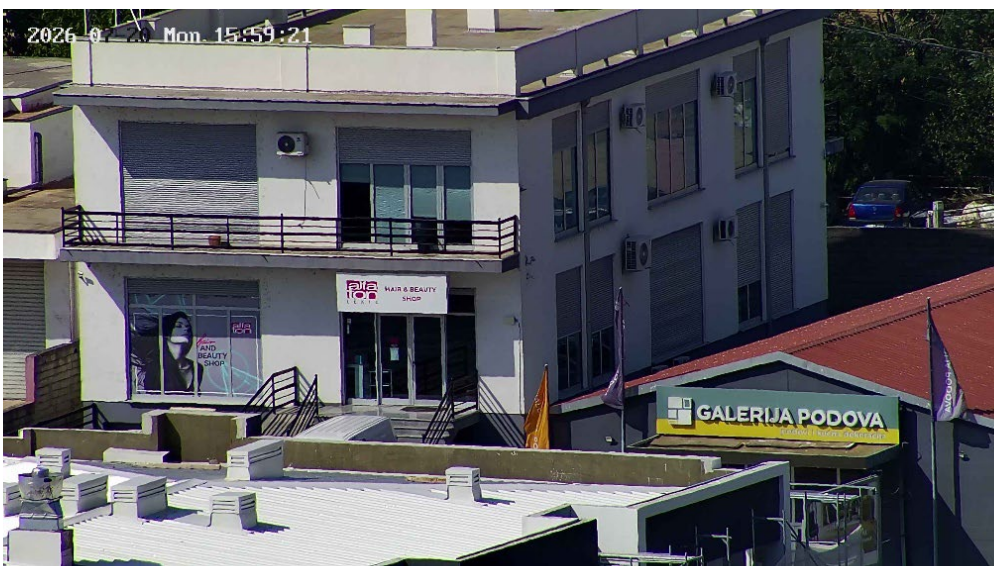


Figure 14. High-magnification image acquired by the PTZ camera, demonstrating the optical zoom capability of Camera 1 for detailed inspection of distant objects.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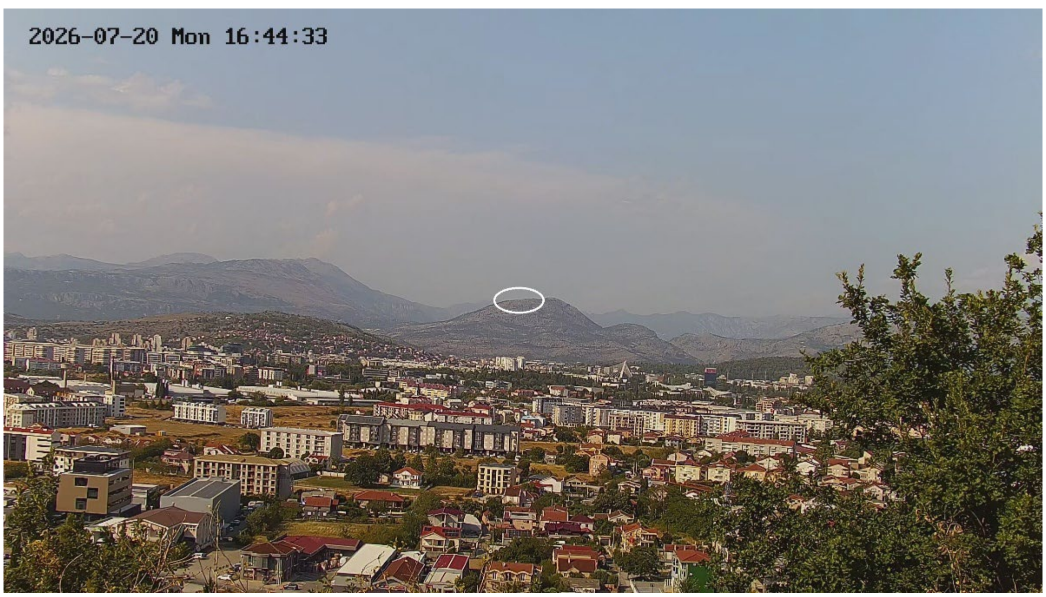
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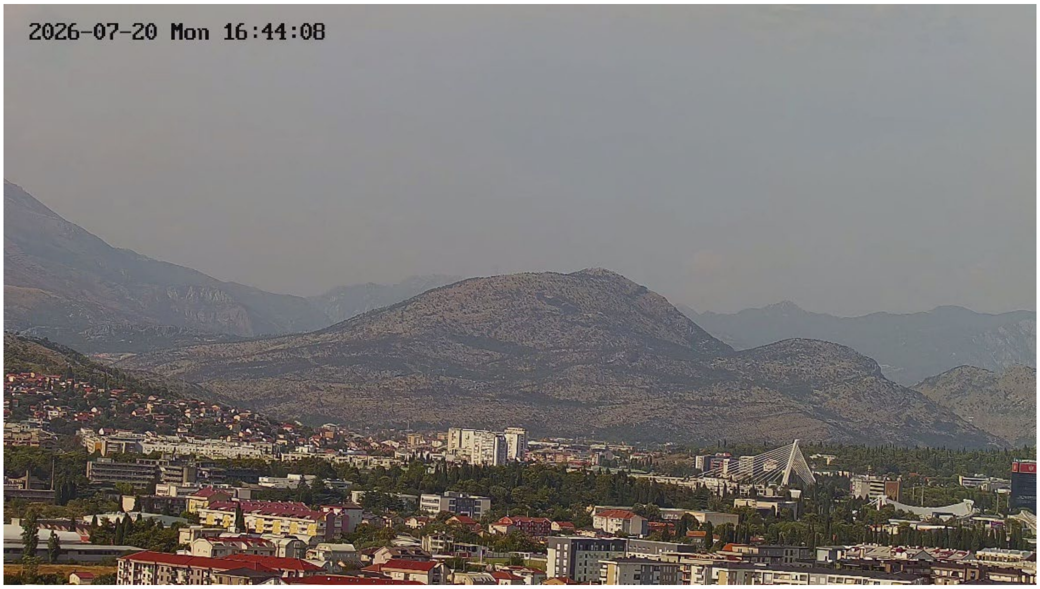

Figure 15. High-magnification image acquired by the PTZ camera, demonstrating the optical zoom capability of Camera 1 for detailed observing distance hills for wild fires with air distance of about 6.5km. Seeing even cars and roads and small objects (details).

3. Technical details

Technical specification:

Camera 1: Hikvision DS-2DE5425IWG-K/4G

Camera 2: Dahua DHI-TPC-BF1241

Solar power source: 80W Polycrystalline Glass Solar Panel Kit, Hikvision, DS-2XS6K01-C36S80

4G Router: Cudy LT300

Power controller: Designed by MECOnet

Sensor gateway: Designed by MECOnet, ESP32 based

M2M (Machine-to-Machine) SIM + packet: https://1.me (One mobile) with **static IP address**.

4. Supplementary data and image resources:

https://drive.google.com/drive/folders/1v_C3fb6dMvllkuKNj_OU3_3ReKLD4tok?usp=sharing

Conclusion

The preliminary testing of the MobileWatchStation prototype at Dajbabska Gora, near Podgorica, Montenegro, successfully verified the integration and operation of the proposed autonomous wildfire monitoring platform under realistic outdoor conditions. The system operated continuously using a photovoltaic power supply and battery storage, while the communication infrastructure ensured reliable connectivity with the MECOnet cloud platform. Live video streams from both the visible-spectrum PTZ camera and the thermal camera, together with environmental sensor data, were successfully transmitted and visualized through the web-based monitoring interface.

The conducted laboratory and field tests verified the correct operation of the principal system components, including autonomous power management, Ethernet and 4G communication, cloud connectivity, remote PTZ control, thermal and visible imaging, environmental sensing, and real-time data visualization. The results demonstrate that the MobileWatchStation provides a reliable hardware and communication platform capable of supporting AI-based image analysis for automated wildfire detection. By combining thermal and visible-spectrum imagery with environmental sensor data, the platform establishes a solid foundation for intelligent fire detection and alarm generation while enabling remote verification of detected events.

The activities presented in this deliverable focused primarily on prototype integration and functional verification rather than quantitative evaluation of wildfire detection performance. The next phase of the project will focus on the development, optimization, and validation of artificial intelligence algorithms for early wildfire detection using multimodal data from the visible and thermal cameras together with environmental sensors. Controlled fire experiments and extended field trials will be conducted to quantify key performance indicators, including fire detection range, detection time, localization accuracy, false alarm rate, communication latency, and overall system availability under varying environmental and meteorological conditions.

Combination of the cameras Hikvision DS-2DE5425IWG-K/4G and Dahua DHI-TPC-BF1241 can be successfully used for surveillance monitoring in diameter of 5km and early detection of wild fires in diameter of 1km.