

CONCEPT FOR TRAINING UAV PILOTS FOR CRISIS RESPONSE USING MINI-DRONES IN INDOOR ENVIRONMENTS

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Abstract: This article aims at a theoretical justification for training novice and intermediate crisis-response UAV pilots with mini-drones in controlled indoor environments. It uses a focused conceptual review that triangulates scholarship on UAV use in disaster response, GNSS-denied and indoor flight, simulation-based education, deliberate practice, situational awareness, and team coordination, and then interprets that literature against a set of practical modules developed in the context of the PACS (Professionals in Action for Crisis Situations) Erasmus+ project. The core argument is that indoor mini-drone training can function as a pedagogically credible bridge between classroom instruction and higher-risk field deployment because it enables safe, repeatable, low-cost, scenario-rich practice in obstacle-dense and access-limited environments. The article's contribution lies not in claiming proven field equivalence, but in showing why the PACS-derived modules on reconnaissance, indoor SAR, flood response, and chemical-spill response form a coherent foundational/intermediate training architecture for crisis-response UAV preparation.

Keywords: Mini-UAV; crisis-response training; indoor UAV training; disaster response; simulation-based learning; GNSS-denied operations; public safety

Background

Unmanned aerial vehicles (UAVs) are now considered a standard tool for rapid disaster assessment, search and rescue, reconnaissance and mapping, structural inspection, and providing up-to-date information to crisis response teams [17, 4]. Analyses of their applications in disaster and public safety indicate that their value lies not so much in technological innovation but in their ability to provide an overview of inaccessible and/or dangerous locations, to rapidly collect up-to-date imagery, and to support decision-making when on-site information is incomplete or delayed [17, 11]. Research in the field of emergency mapping highlights that timely aerial imagery can significantly improve the situational awareness of civil protection actors, while analyses of large-scale incidents show that remotely acquired visual information can effectively complement voice communication between dispersed teams [1, 2].

The operational importance of technologies should not be equated with the level of development of training systems. Doud et al. identify training as one of the four main categories of application of unmanned aerial vehicles in disasters [17]. However, this area remains significantly less developed compared to areas such as mapping of affected areas or assisting in rescue operations. The scientific literature dedicated to drone training considers and explores various approaches based on the use of scenario and simulation methods, especially in the context of training remote pilots and sensor system operators [17, 16, 21]. However, methodological models developed specifically for training novice UAV operators

intended for crisis response activities remain relatively limited. The literature dedicated specifically to training with mini-drones in controlled indoor spaces is even less developed. The resulting discrepancy has both practical and theoretical dimensions. Government institutions and universities need training environments that are safer and more cost-effective than real-world operational environments. At the same time, these simulation environments need to be more realistic and task-oriented than traditional classroom-based training.

The concept presented in the article is based on the PACS project (“Professionals in Action for Crisis Situations”; project No. 2024-1-RO01-KA220-VET-000252081) – a cooperation project under the “Erasmus+” program. The developed training module under the PACS project “Practical exercises for training and preparation of UAV pilots using drones and robotics with artificial intelligence in disasters, accidents and crises” segments the training task into four interconnected practical sub-modules:

- Exercises in reconnaissance and surveillance using drones, including visual information, thermal, and spectral imagery;
- Simulation exercises for responding to an indoor Search and Rescue (SAR) scenario;
- Simulation exercises for responding to an indoor flood scenario;
- Exercises for responding to a chemical spill.

The article conceptually justifies the architecture for practical training in indoor spaces, based on mini-drones through controlled simulation models. The study is based on a review of the specialized literature. The argumentation is built by comparing academic research in the areas of UAV use in disasters, indoor navigation, simulation pedagogy and human factors. The conclusions obtained are interpreted in the context of the developed practical training modules, which represent the applied goal of the study. The PACS UAV training modules integrate clear safety procedures, role allocation, reporting tasks, mapping requirements and evaluation criteria.

The thesis of the article is that the developed conceptual model for training UAV pilots for crisis response can function as a fundamental or intermediate transition between theoretical training and the real operational use of UAVs in the field, without replacing subsequent training in an open environment, at a higher level of complexity or using advanced sensor systems. The four practical training modules on UAV control, developed under the PACS project, are considered in the article as the final applied result of the theoretical synthesis carried out.

1. Literature review and theoretical framework

The literature suggests two reasons why preparing for indoor crisis response deserves special attention. First, many of the operationally important tasks in the use of unmanned aerial vehicles (UAVs) in crises are informational in nature: locating victims, identifying blocked roads, mapping the extent of the hazard, inspecting facilities, and transmitting information and/or conclusions derived from the images to the incident command center [17, 16, 21]. Second, the environment in which such tasks occur is often cluttered, with limited access, or partially devoid of GNSS signal. Reviews of GNSS-independent navigation emphasize that satellite positioning is absent or unreliable indoors and of degraded quality in urban and similar environments, which complicates perception, localization, obstacle avoidance, and control of UAVs [10]. Research in indoor search and rescue robotics confirms this: obstacles, uncertainty, and searching for victims in confined spaces are not extreme cases, but fundamental operational challenges [20].

Although direct evidence on training in indoor crisis management with mini-drones remains limited, the related learning theory does offer a sound framework. Experiential learning views its essence as a process that is shaped by cycles of action, reflection,

conceptualization, and reapplication [14]. Purposeful practice involves the requirement for repeated, goal-directed performance accompanied by feedback and correction [8]. Simulation research, although developed primarily in medicine and aviation crew training, has consistently shown that effective learning environments combine repetitive exercises, gradually increasing task complexity, instructor feedback, and post-exercise debriefing [12, 9]. Applied to UAV training, these principles favor controlled scenarios where errors are tolerated, corrected, and repeated rather than punished with severe operational consequences. Research in drone-specific training has reached a similar conclusion: scenario-based simulations can move from basic UAV flight skills to higher-level judgment and logical thinking in mission execution [7].

This approach also clarifies that training for crisis response is not limited to skills in controlling the speed, acceleration and position of the aircraft. The Endsley model views situational awareness as perception, understanding and prediction [7]. Analyses of cognitive tasks in unmanned aerial vehicles also show that pilots must assess ambiguous situations, notice implicit signals, communicate clearly, deal with technical malfunctions and make decisions under time pressure [15, 16]. Research in the field of team effectiveness identifies mutual control, adaptability, supportive behavior and discipline in communication as essential elements of reliable operation in dynamic conditions [18]. For the preparation of UAV pilots for crisis response, flight skills are necessary but not sufficient: perception, interpretation, mapping, reporting and coordination are equally important training objectives.

2. Development of a concept for indoor mini-drone training for crisis response

A conceptual training platform for indoor training with mini-drones needs to optimize safety, reusability and controllability, rather than payload capacity. In our opinion, the UAV training modules developed under the PACS project do just that. They illustrate equipment criteria that prioritize small bodies, preferably under 250 g, with propeller guards or a protective cage, low noise, moderate power, stable hover/altitude control, reparability, spare batteries and basic fail-safe features. The training concept also considers UAV flight in line of sight as a baseline and FPV as an optional or advanced operation. This approach is best viewed as a reasonable logic for structuring the concept rather than a strict empirical threshold: the literature does not prove that 250 g is a universal pedagogical limit, but the reduced mass, protected propellers, low-speed flight, and easy reparability reduce the consequences of novice errors and increase the frequency of re-attempts. Clear boundaries, observers, pre-flight checks, emergency landing procedures, and explicit role assignments transform hardware selection into a culture of safety rather than simply a list of technical equipment.

The reconnaissance and surveillance sub-module (Exercises in reconnaissance and surveillance using drones, including visual information, thermal, and spectral imagery) defines the basic framework of the learning structure. It essentially combines the individual elements of control, take-off, landing, hovering, slow maneuvers, camera use, motion detection, low-light or thermal imaging navigation, introduction to spectral literacy, covert or discreet surveillance, structured reporting, and a short reconnaissance-style mission simulation. The significance of this module is that it redefines the concept of “basic training” by expanding it beyond purely manual control. Working with UAVs in crisis response is primarily characterized by the construction of a consistent operational chain – from the perception and interpretation of information from the environment to its structured transmission in the form of an operational report. The aircraft must be controlled sufficiently

stably for the observation to be meaningful – the camera must be pointed precisely; movement and anomalies must be detected; and the findings must then be expressed in a structured format.

The use of a SALUTE-type reporting structure in the module has significant analytical value. This value does not arise from the mechanical transfer of a military template to the public safety field, but from the ability of standardized, concise reporting to assist trainees in structuring their observations. Such a format encourages the distinction between objectively perceived facts and subjective impressions. At the same time, it supports the acquisition of skills for accurately reporting location, time, and essential details under operational pressure. Thermal and spectral elements should be considered primarily as a component of sensory awareness training. Even when the drones used in the initial stage for indoor operations do not allow the integration of advanced payloads, trainees can form an early understanding of the role of different detection modes. In this way, an awareness is built that the choice of sensor technology changes both what becomes visible and detectable and what information becomes operationally meaningful [1,11].

The indoor search and rescue sub-module - Simulation exercises for responding to an indoor Search and Rescue (SAR) scenario - further clarifies and emphasizes the importance of indoor training. It demonstrates in a practical way that such training creates the conditions for developing skills that are directly applicable to real-life emergency response operations. The module requires trainees to locate survivors in a simulated area of debris or collapsed structure, overcome obstacles in confined spaces, establish and communicate the location and condition of victims, and prepare a basic map for planning the rescue operation. This is not a simple obstacle course dressed up in disaster terminology. This is a structured search exercise that combines low-speed UAV control with the application of a sector principle of observation, target confirmation, brief reporting, and spatial presentation of post-flight results. In areas with degraded GNSS signal, pilots cannot rely on trouble-free stabilization and must constantly assess distance, angle, obstacles, and camera perspective. The mapping task is of particular importance, as it transforms the three-dimensional operational experience gained during the flight into a structured and shareable information product. In this way, the collected spatial data becomes an operational artifact that can be effectively used by ground teams in planning, coordinating, and executing field operations. This step establishes the functional link between flight operations and the decision support process. Literature in the field of search and rescue (SAR) clearly emphasizes the importance of such competencies and operational capabilities. Although UAVs have significant potential to support search operations, their real operational value is realized only when operators are able to conduct a systematic search, communicate their observations in a clear and structured manner, and provide information that effectively supports the follow-up actions of field teams [10, 20, 22].

The third sub-module, Simulation exercises for responding to an indoor flood scenario, is situationally different but pedagogically consistent. It places trainees in a simulated flooded urban microenvironment where they have to survey the flooded area, distinguish between dangerous and safe evacuation zones, assess routes and perform a simulated delivery of light rescue equipment. The flood response literature has already convincingly demonstrated the usefulness of aerial reconnaissance for identifying flooding patterns, access issues to affected areas and determining priority areas for intervention [11,

19]. In this context, the structure of the PACS training modules transforms such an operational need into a compact training exercise, implemented in an indoor environment by using a scaled scene and clear visual coding of the elements of the situation. The real value of this approach is not in attempting to simulate full-scale field logistics by dropping a payload from a micro drone. Its significance is pedagogical and analytical. The exercise forces trainees to integrate aerial surveillance with the operational prioritization process, thereby linking information gathering to decision-making in the context of crisis response. The team must decide what is considered a safe route, what is considered a dangerous area, and how to fly with sufficient precision to achieve a specific objective. The delivery task therefore functions less as a logistical trick and more as a means of precise control, prioritization of resources, and mission sequencing under time and battery power constraints.

The fourth sub-module, Exercises for responding to a chemical spill, is perhaps the most striking example of why training for operating unmanned aerial vehicles (UAVs) in a crisis situation should encompass more than just piloting. The module tasks trainees with conducting aerial reconnaissance of a contaminated area, mapping “hot” and “warm” areas, transmitting visual or simulated sensor data to a command center, and identifying safe entry points for response teams. The logic of the exercise is clearly oriented towards crisis management. Trainees are required to transform visual information first into zoning, then into communication, and finally into route recommendations for other participants in the operation. Reviews of the scientific literature on chemical contamination detection highlight that small drones can effectively assist in the assessment of hazardous environments and reduce the risk of exposure by bringing measurement tools closer to the source of contamination [1, 3, 11]. The PACS UAV training modules translate this principle into a basic training format using visual coding, manual or on-screen mapping, information transfer procedures, and analysis of safe access points. The simulated command center component is of particular importance, as it demonstrates that the operational value of a drone does not end with the capture of images. Information must be transmitted, validated, interpreted, and used to take action. In this way, training moves from simply “flying in a room” to real-world support for crisis management workflows.

Within the conceptually argued and presented four practical sub-modules of UAV control under the PACS project, a clearly structured hierarchy of competencies and capabilities for practical actions is outlined. The sequence moves from basic aircraft control and surveillance, to target search and navigation in enclosed spaces, then to route analysis and precise payload delivery, and finally to hazard zoning, communication with a command center and planning safe entry points. Equally important, the assessment criteria set out in the modules are not limited to whether the aircraft remained in the air. The document consistently assesses piloting accuracy, situational awareness, successful mission execution, mapping accuracy, communication clarity, teamwork, risk interpretation, delivery accuracy and safe maneuvering of the UAV. This is precisely the appropriate direction for assessment within a curriculum aimed at responding to crises. Competence in this area is inherently multidimensional. A pilot who flies the aircraft technically accurately but reports vaguely is, in our view, mapping inaccurately or ignoring the spotter’s instructions, and therefore cannot be considered successful in the context of crisis response operations. The module package should also include systematic debriefing sessions and reflective discussion after each exercise. In this way, the training design is consistent with the broader literature on

simulation-based training, which views feedback and debriefing as central rather than additional elements of the learning process [9, 12].

3. Discussion: necessity, relevance, potential, limitations and applicability

The need for the presented concept should be understood primarily as a curriculum-based one, not a technological one. Institutions involved in crisis response are increasingly faced with a dual challenge: on the one hand, UAVs have an increasing operational importance, and on the other hand, access to training conditions close to real-life conditions is limited by factors such as cost, weather conditions, regulatory requirements, infrastructure and operational risk [5]. The PACS project explicitly aims to improve the quality of crisis management training by developing an integrated training course, creating guidelines for good practices and producing practical and video-based training materials. In this context, the indoor mini-drone training modules analyzed and tested here represent a particularly coherent response. They provide a training layer that is practice-oriented and mission-oriented, yet controlled enough to minimize novice errors, allow close instructor supervision and ensure a high degree of repeatability. They are therefore well aligned with the broader logic of the “Erasmus+” vocational training program, which is oriented towards applied, transnational and competence-based learning.

The broader pedagogical value of this approach is manifested in the way it structures the preparation for skills transfer. Transfer is never automatic and the article does not claim otherwise. However, the concept is powerful because it reproduces precisely the sequence of actions through which UAVs create value for public safety: mission briefing, take-off, controlled observation, identification of significant features, structured reporting, mapping, communication with the command function and subsequent reflective debriefing. The theory of experiential learning explains why the action-reflection cycle is essential. The concept of purposeful practice emphasizes the importance of repeatedly performing clearly formulated tasks. Simulation training research shows why debriefing, instructor feedback, and gradual increase in complexity enhance learning, and human factors theory emphasizes the need for situational awareness and team coordination to be built into training. PACS modules combine these elements with particular clarity. They allow trainees to make mistakes at low cost and high safety, to repeat exercises quickly, and to gradually connect aircraft control to its operational significance.

However, the concept also has real-world limitations. Indoor scenarios and mock-ups inevitably simplify reality. They cannot fully replicate atmospheric conditions, smoke, noise from stressful environments, unstable debris, toxic substance spread, crowd pressure, broken communications, or the emotional intensity of real-world incidents. Mini-drones also have limited flight duration and limited payload and sensor accuracy capabilities, and indoor flights in line-of-sight conditions cannot adequately prepare trainees for future operations with larger platforms, more complex communication architectures, or more advanced sensor systems. The additional workload on instructors is another significant factor. Quality scenario building, observation, feedback, and evaluation require time and consistency, and in the absence of standardized evaluation criteria, different groups of trainees may receive uneven evaluations. Indoor magnetic interference and lack of GNSS signal can also be both pedagogically beneficial and technically challenging, as they complicate flight stability and novice confidence. Regardless of these considerations, none of these limitations invalidate the concept, but rather clearly outline its useful limits.

Therefore, indoor mini-drone training should be positioned as a basic or intermediate level within a broader curriculum, and not as a substitute for training in a real outdoor environment. The appropriate progression is cumulative and follows the sequential building of competencies and capabilities. The first stage can include theoretical training and familiarization with the regulatory framework in a training environment. This is followed by basic training through simulators or instructor induction. This is followed by scenario-based training with indoor mini-drones, which allows for controlled practical training. The next stage is conducting outdoor missions in direct line-of-sight conditions with UAVs. Only then do we proceed to more complex operations, including the use of advanced sensors, larger platforms, searching in wider areas, working with degraded communications or inter-agency coordination. In this sense, the practical training modules on UAV management in crises, developed within the PACS framework, can best be considered as theoretically sound, operationally relevant and practically scalable. Although not yet definitively empirically validated, they clearly deserve integration into multi-level educational programs to prepare UAV operators for crisis response.

The four practical sub-modules, conceptually presented for training in the control of unmanned aerial vehicles (UAVs) under the PACS project, highlight the possibility of borrowing the model in building competencies and capabilities for practical actions in high-risk situations of attacks and unauthorized intrusions on board ships with role-playing of possible situational models by crew members responsible for the security of the ship [13].

Conclusions and recapitulations

This article argues that the growing operational importance of unmanned aerial vehicles (UAVs) in crisis response does not eliminate the need for sustainable training concepts, but rather further emphasizes it. The contribution of the study is not to present yet another overview of the use of drones in disasters, but to provide a theoretical justification for a specific pedagogical architecture - training UAV pilots for crisis response through scenario-based training in an indoor environment using mini-drones.

By comparing the scientific literature in the field of disaster response, research on navigation in conditions of GNSS signal absence, simulation training theory, human factors research, and studies dedicated to the competencies of remote pilots, the article shows why controlled indoor training environments can support the development of basic and intermediate competencies and capabilities. These include precision piloting, observation, sensor awareness, structured reporting, mapping, communication, teamwork, and decision-making based on risk and safety assessment.

Within this argument, the four modules presented, developed under the PACS project, emerge as a logical applied result of the review, rather than as an arbitrarily selected set of exercises. Their value lies precisely in their clearly defined boundaries. They do not replace outdoor training, advanced sensor work, or full-scale field training, but they provide a serious, scalable, and theoretically sound transition to them.

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