



**Unmanned Aerial Vehicles in
accident investigation:
capabilities, operational challenges,
and technological priorities**

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1 *Executive summary*

Unmanned Aerial Vehicles (UAVs) have rapidly become essential tools in modern accident investigation, offering new capabilities for evidence collection, site documentation, and hazard assessment. Their ability to capture high-resolution visual and spatial data, access hazardous areas, and accelerate the investigative timeline has transformed practices across aviation, road traffic, maritime, and rail sectors.

Despite this strong potential, several barriers still constrain the full operational value of UAVs. These include regulatory constraints, environmental limitations, restricted flight endurance, operator training variability, and challenges in managing large volumes of data. As UAV technology continues to evolve, addressing these obstacles will be critical to supporting safer, faster, and more efficient investigative operations.

This whitepaper presents a consolidated analysis of current UAV capabilities, operational experiences, common challenges, and future technological priorities, providing guidance for regulators, investigators, safety authorities, and industrial stakeholders.

2 *Introduction*

Accident investigation relies on accurate, timely, and comprehensive data collection to determine causal factors and support safety improvement initiatives. Traditional on-site methods often expose investigators to hazardous environments, require significant time and manpower, and may leave information gaps due to environmental or logistical constraints.

UAV technology offers a complementary approach that enhances:

- Safety, by reducing the need for personnel to enter hazardous areas
- Efficiency, through rapid scene documentation and large-area coverage
- Data quality, thanks to high-resolution imaging, thermal sensors, and advanced
- Analytical precision, enabling accurate 3D reconstruction and spatial interpretation

These advantages have encouraged growing adoption across investigative domains. However, their integration into formal investigative frameworks requires balancing their benefits with operational, technological, and regulatory challenges.

3 *The role of UAVs in accident investigation*

UAVs are now used across multiple sectors, each with distinct requirements and operational contexts. Their versatility stems from a combination of payload options, autonomous navigation capabilities, and advanced data processing tools.

UAV technology offers a complementary approach that enhances:

High-resolution imaging and mapping

Modern UAVs equipped with RGB cameras, LiDAR sensors, or thermal imaging systems can produce:

- Ortho-mosaic scene maps
- 3D terrain and wreckage models
- Heat distribution patterns
- Point clouds for site reconstruction

These outputs improve visibility of debris distribution, impact geometry, and scene boundaries.

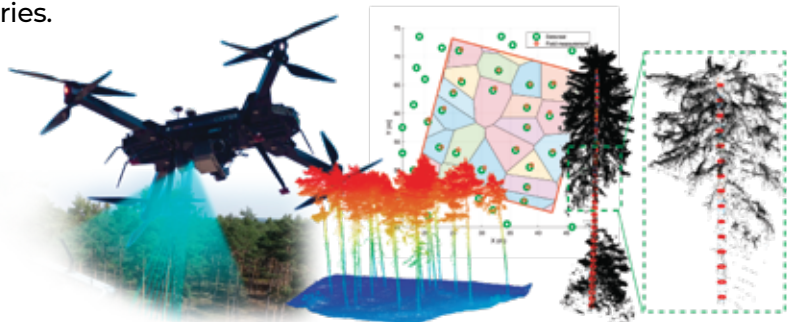
Hazard identification and safety assessment

UAVs play a critical role in identifying hazards that may compromise the safety of investigators and first responders. Through high-resolution imaging, thermal sensors, and other specialized payloads, these systems can detect the presence of flammable liquids, assess the condition of damaged or unstable structures, and reveal potential electrical hazards such as exposed or downed powerlines. They are also capable of identifying environmental contaminants that may not be visible from the ground, including chemical residues or dispersed particulate matter. By providing this information rapidly and without requiring personnel to enter dangerous areas, UAVs significantly improve situational awareness and support informed planning for safe site access and operational decision-making.

Flight path and wreckage reconstruction

Elevation models, vegetation disturbance patterns, and topographical features can be analysed to infer final aircraft or vehicle trajectories.

- Ortho-mosaic scene maps
- 3D terrain and wreckage models
- Heat distribution patterns
- Point clouds for site reconstruction



Coverage of large or inaccessible areas

UAVs excel in environments where:

- Terrain is unstable
- Access is obstructed
- Weather or ground conditions limit mobility
- Waterborne incidents occur

These capabilities streamline the investigative timeline and increase data completeness.

4 *Operational experience and best practices*

Investigators and UAV operators consistently highlight several best practices required to ensure effective missions.

4.1 Pre-deployment planning

Regulatory compliance

Clearance must be obtained for operations in controlled airspace, near critical infrastructure, or over private land. Investigators often face procedural delays when operating near airports or sensitive zones.

Weather assessment

Adverse conditions such as wind, rain, and low visibility significantly impact UAV stability and data quality. Weather-related no-fly decisions remain one of the most common operational constraints.

Equipment inspection

Reliable performance depends on:

- Battery health monitoring
- Sensor calibration
- Firmware/ software updates
- Redundancy checks for communication links

Site-specific risk evaluation

Terrain, environmental hazards, and population density dictate the flight strategy, operator positioning, and choice of UAV type.

Comprehensive flight planning

Detailed planning ensures optimal sensor coverage, while contingency procedures help manage communication loss, battery depletion, or unexpected obstacles.

4.2 Frequency and context of use

Although UAVs are increasingly recognized as essential, deployment frequency still depends on:

- Investigator experience
- Regulatory environment
- Scene complexity
- Availability of equipment and trained operators

5 Performance Assessment

Investigators typically evaluate UAVs across four dimensions:

Image and data quality

UAVs provide high-resolution imagery suitable for measurement, 3D modelling, and evidence interpretation. Thermal and LiDAR data enhance visibility in low-light or complex scenes.

Safety enhancement

Remote observation significantly reduces investigator exposure to hazardous environments, although this benefit varies by scenario.

Accuracy of site documentation

UAV-based mapping improves the precision of scene boundaries, debris fields, and impact signatures.

Overall investigative value

UAVs consistently reduce time on scene, expedite analysis, and improve situational awareness.



6 *Key challenges limiting UAV effectiveness*

Despite the demonstrated advantages, several persistent obstacles continue to hinder efficient UAV deployment.

6.1 Environmental and site-related barriers

- Dense vegetation, steep terrain, or unstable surfaces may complicate launch/landing operations.
- Hazardous materials, fire zones, or debris fields require careful flight path management
- Weather remains one of the most significant operational risks, especially for small multirotor UAVs.

6.2 Regulatory constraints

Regulatory frameworks vary widely across jurisdictions and often impose limitations related to:

- Beyond Visual Line of Sight (BVLOS) operations
- Surveillance restrictions in populated areas
- Air Traffic Control approval requirements
- Privacy and data protection mandates

These constraints can delay deployments and reduce investigative flexibility.

6.3 Data management limitations

UAVs generate large datasets, particularly when using LiDAR or high-resolution sensors. Key challenges include:

- Processing bottlenecks in converting raw data into interpretable products
- Storage limitations on-site or on-board
- Data security concerns, including risk of unauthorized access or corruption
- Bandwidth constraints for real-time transmission
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An absence of standardized data workflows across investigative agencies further complicates integration.

6.4 Human factors

- Operator skill levels vary widely.
- Limited training opportunities create inconsistencies in data quality.
- Situational pressure during accident responses may introduce procedural errors.

7 *Technological priorities for Future UAV integration*

Feedback from investigators and operational experience highlights several areas where technological development is essential to fully leverage UAV capabilities in accident investigation. These priorities relate to endurance, sensing performance, data processing, autonomy, and advanced analytics, all of which influence the effectiveness and reliability of UAV deployments in demanding investigative environments.

7.1 Extended battery life

Flight endurance consistently emerges as the most critical technological limitation. Longer battery life is essential not only to cover large and complex accident sites but also to allow UAVs to perform multiple repetitive passes without interruption. Extended endurance also supports prolonged hover operations when detailed inspection or close-range imaging is required. With current systems often constrained by short operational windows, improvements in power storage or hybrid propulsion would substantially reduce mission interruptions and the need for frequent battery replacements, thereby increasing efficiency and reducing the potential for gaps in data collection.

7.2 Enhanced imaging technologies

Imaging capability is central to the investigative value of UAVs, and enhancements in this area would significantly improve the fidelity of collected data. Higher-resolution optical sensors enable more accurate visual documentation, while advances in thermal imaging increase the ability to detect heat sources, hotspots, or submerged elements that may not be visible with standard cameras. Improvements in LiDAR accuracy, range, and point-cloud density would also facilitate the creation of more precise three-dimensional models and detailed reconstructions of accident scenes. Together, these imaging advancements would support deeper analysis, enable automated measurement extraction, and strengthen the evidentiary precision of UAV-derived outputs.

7.3 Real-time data processing and edge computing

Real-time or near-real-time data processing represents another major technological need. On-board computing would enable UAVs to analyse imagery and sensor inputs during flight, allowing investigators to detect hazards more quickly, assess scene completeness immediately, and make in-mission adjustments without returning to a ground station. Edge processing capabilities would also reduce dependence on external infrastructure, which is particularly valuable in remote or communication-limited environments. By generating preliminary reconstructions or hazard maps on the fly, UAVs could accelerate decision-making during the most time-critical stages of an investigation.

7.4 Autonomous flight capabilities

Increasing levels of autonomy are expected to play a pivotal role in future accident investigation missions. Automated flight planning and grid mapping can ensure consistent coverage of large sites, while autonomous take-off and landing systems reduce operator workload and mitigate human error. Integrated obstacle detection and avoidance capabilities enhance safety in complex environments, especially when flying near debris, structures, vegetation, or unstable terrain. As autonomy evolves, UAVs will be able to interpret their surroundings more effectively, adjust flight paths dynamically, and maintain optimal data-gathering trajectories even under difficult operational conditions. These capabilities will, in turn, support more systematic and reliable data acquisition.

7.5 AI and machine learning for data analysis

Artificial intelligence and machine learning are poised to transform how UAV data is processed and interpreted. These technologies can automate debris classification, detect patterns in terrain disturbance, and support predictive modelling of collision dynamics, significantly reducing the time required for manual analysis. Machine learning algorithms can also aid in identifying anomalies or inconsistencies within large datasets, drawing investigator attention to subtle indicators that may otherwise go unnoticed. As datasets continue to grow in complexity and volume, AI-driven tools will become essential for extracting meaningful insights quickly and accurately, ultimately enhancing the overall investigative workflow.



7.1 Extended battery life



7.2 Enhanced imaging technologies



7.3 Real-time data processing and edge computing



7.4 Autonomous flight capabilities



7.5 AI and machine learning for data analysis

8 *Strategic considerations for industry and regulators*

To fully harness the potential of UAVs in accident investigation, coordinated progress is required across regulatory, technological, and operational domains. A first priority is regulatory modernization. Harmonized standards are needed to support emergency UAV deployment in controlled and uncontrolled airspace, reducing the complexity investigators face when operating across jurisdictions. Streamlined approval mechanisms—particularly fast-track authorizations for accident response in or near restricted areas—would significantly reduce deployment delays. Likewise, expanding permissions for Beyond Visual Line of Sight (BVLOS) operations under rigorously controlled conditions would allow investigators to survey large or remote sites more efficiently.

Progress is also necessary in data governance. Accident investigations increasingly depend on high-volume datasets, making secure and interoperable data infrastructures essential. Establishing consistent approaches to file formats, metadata labeling, and audit trails would enhance the integrity and traceability of collected data. At the same time, reliable communication channels capable of supporting real-time or near-real-time data transmission are critical, particularly for time-sensitive missions or multi-agency collaboration.

Training and competency development represent another cornerstone of effective UAV integration. Formalized certification pathways tailored specifically to investigative UAV operations would help ensure consistent levels of operator proficiency. Simulator-based training should become a standard component of preparation, enabling operators to practice missions in hazardous, complex, or constrained environments without risk. Cross-sector standardization of training approaches would further contribute to more uniform operational practices across aviation, maritime, rail, and road investigation domains.

Finally, strategic investment in more resilient UAV platforms is essential for supporting demanding investigative missions. Future systems must demonstrate greater resistance to adverse weather, incorporate redundant communication and control architectures, and offer payload flexibility to accommodate a growing range of imaging and sensing technologies. Advanced onboard safety mechanisms and increased automation will also be key to ensuring consistent and reliable performance during high-stakes data collection.



*At the cutting-edge of
technology*



9 Conclusion

UAVs have become indispensable tools in accident investigation, significantly enhancing data quality, investigator safety, and operational efficiency. Their strengths in mapping, hazard assessment, and scene reconstruction have reshaped investigative practices across aviation, road, rail, and maritime domains.

However, their full potential remains constrained by regulatory complexity, limited flight endurance, data management bottlenecks, environmental vulnerability, and variations in operator expertise. Continued advancements in autonomy, sensing technologies, power systems, and AI-driven analytics will be essential to address these challenges and support more robust investigative capabilities.

As UAV operations become increasingly complex and demand more reliable control architectures, the integration of certified, safety-oriented flight control systems such as Veronte Autopilot becomes particularly relevant. High-integrity autopilot platforms with redundant architectures, deterministic behavior, and advanced mission automation can play a critical role in enabling safer deployment, improving operational reliability in constrained or hazardous environments, and supporting the precision required for forensic data collection. Their contribution is especially important as accident investigation missions expand toward autonomous mapping, BVLOS operations, and dynamically adaptive flight paths.

A coordinated effort between regulators, investigators, technology developers, and system integrators—supported by high-reliability autopilot solutions—will be essential to ensure that UAVs continue to evolve into a mature, dependable, and central component of modern accident investigation frameworks.

