

Effect of Incomplete Crime Scene Recovery on Forensic Attribution in Electrically Initiated IED Investigations: A Case-Based Analysis

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Abstract

Improvised explosive devices (IEDs) are frequently employed in targeted attacks due to their adaptability and the accessibility of explosive precursors. Post-blast forensic investigation plays a vital role in reconstructing the incidents, identifying explosive materials, and supporting investigative acknowledgement. However, the reliability of forensic interpretation depends largely on the completeness and integrity of evidences identified and collected from the crime scenes. This work presents a forensic examination of an electrically initiated improvised explosive device (IED) incident in which only limited physical evidence was available/recovered for laboratory analysis. Two exhibits were received for examination: (i) a questioned electrical wire recovered from the crime scene and (ii) a control electrical wire submitted for comparative analysis. Chemical and instrumental examinations were conducted to detect inorganic explosive ions and organic explosive compounds, including nitrate, ammonium, sodium, potassium, TNT, RDX, PETN, and HMX. Additionally, comparative physical examinations of the wires were performed to evaluate structural characteristics such as copper strand configuration and electrical resistance. Analytical results revealed that there is no detectable explosive residues available on the questioned wire. Additionally, comparative examination demonstrated clear differences in copper strand count and electrical resistance between the questioned and control wires, indicating that the two exhibits were not identical. The absence of additional critical components, such as detonators, explosive residues, or container fragments, considerably restricted the scope of forensic reconstruction of the crime scene. These findings highlight the critical importance of comprehensive crime scene evidence recovery in post-blast investigations, as incomplete evidence collection can substantially limit forensic interpretation, attribution, and the overall evidentiary value of laboratory examinations.

Keywords: Electrically Initiated IED, Forensic Attribution, Crime Scene Recovery, Evidence Comparison, Explosive Residue Analysis, GC–M sand Incomplete Evidence

1. Introduction

Improvised explosive devices (IEDs) continue to represent a major threat in both criminal and terrorist incidents due to their destructive capability and the easy availability of explosive precursors and triggering components [1–4]. These devices are typically constructed using combinations of explosive materials, power sources, switching mechanisms, detonators, and electrical conductors. Following detonation, explosive devices typically fragment and disperse components over a wide area, which complicates forensic reconstruction and identification of device components [2,3,5].

Post-blast forensic investigation plays a crucial role in identifying explosive materials, reconstructing the device architecture, and generating investigative leads [2,6].

The success of such investigations depends heavily on the systematic recovery of physical evidence from the explosion scene and the application of appropriate analytical techniques in the forensic laboratory. Evidence recovered from post-blast scenes commonly includes detonator fragments, wiring materials, explosive container debris, and residues of explosive compounds dispersed within the surrounding environment [2,7].

Modern analytical techniques for explosive residue detection include gas chromatography–mass spectrometry (GC–MS), liquid chromatography–mass spectrometry (LC–MS), ion chromatography, ion mobility spectrometry, Raman spectroscopy, and infrared spectroscopy [8–12]. These analytical methods enable identification of a wide range of explosive compounds including nitroaromatics such as

TNT, nitramines such as RDX, nitrate esters such as PETN, and inorganic oxidizers including nitrate, chlorate, and perchlorate salts [9–13].

In addition to chemical identification of explosive residues, the forensic examination of device components can provide valuable information regarding the design and triggering mechanism of the explosive device. Electrical components such as wires, switches, and detonators may exhibit distinctive structural characteristics that can assist in associating recovered fragments with particular manufacturing sources or supply chains [2,15,16].

The reliability of forensic reconstruction is strongly dependent on the completeness and quality of evidence recovered during the initial crime scene investigation [6, 17–19]. Inadequate recovery of device fragments or explosive residues can significantly restrict the scope of laboratory examination and limit the ability of forensic scientists to determine the explosive composition or reconstruct the initiation system of the device.

Previous research has demonstrated that detonator fragments and debris located near the seat of explosion frequently contain the most informative forensic evidence, including explosive residues and identifiable device components [7,20]. Failure to recover these critical materials may prevent accurate reconstruction of the explosive device and weaken the evidentiary value of laboratory findings.

The present study describes a forensic examination conducted following an electrically initiated IED incident in which only a limited number of exhibits were recovered from the crime scene. Specifically, a segment of electrical wire believed to have been used as the command wire for detonation was submitted for examination along with a control wire for comparison. Through chemical analysis and comparative physical examination, this study highlights the analytical constraints encountered when critical device components are not recovered during crime scene investigation and emphasizes the importance of comprehensive evidence recovery in post-blast forensic analysis. The analytical workflow for this study is illustrated in Figure 1.

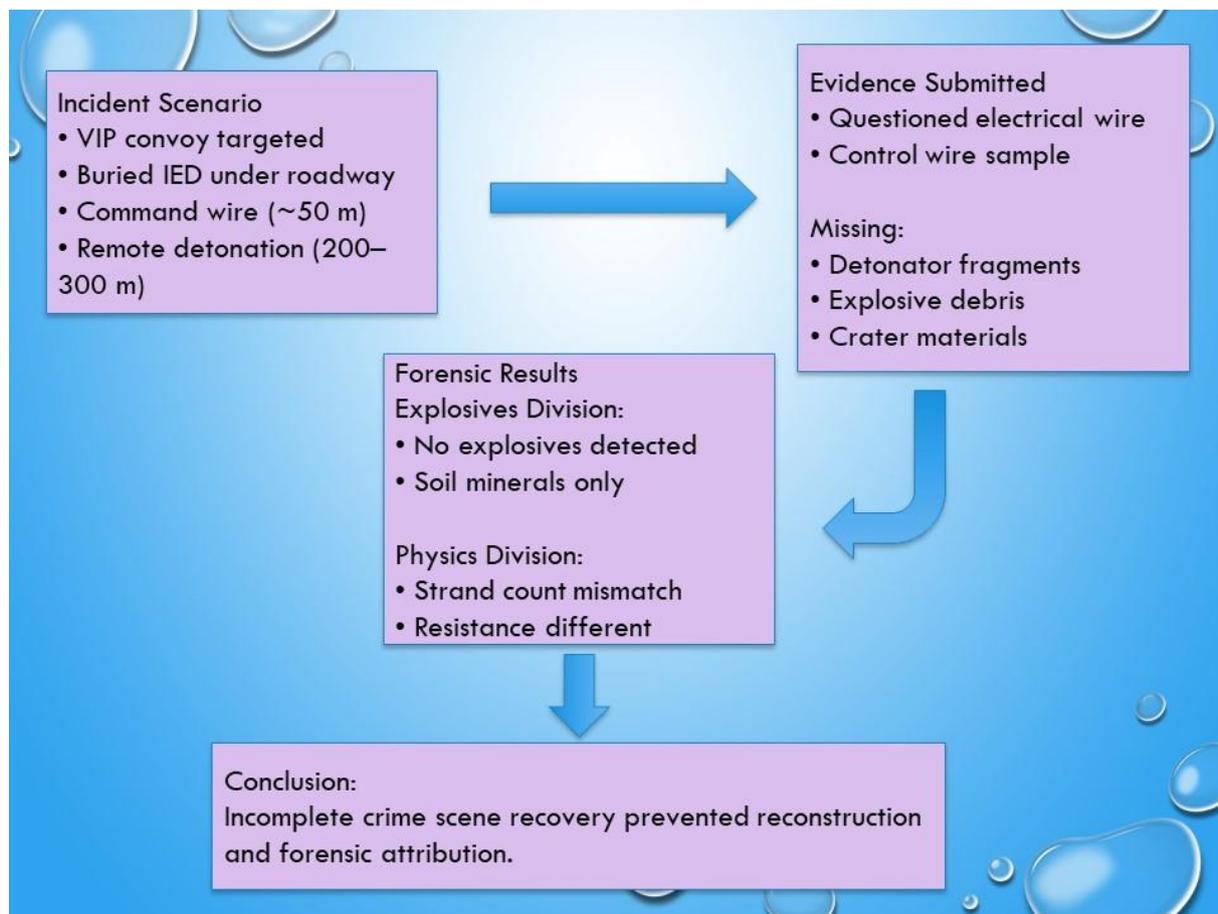


Figure 1: Investigative and Analytical Workflow in the Examination of the Electrically Initiated IED

1.1. Literature Review

Post-blast investigation has become an essential component of modern forensic science due to the increasing use of improvised explosive devices in criminal and terrorist incidents [1,2,20]. The primary objectives of such

investigations include identifying the explosive material, reconstructing the device configuration, and establishing forensic links between device components and suspects.

Explosive residues may persist on fragments such as detonator

components, wiring materials, and container debris even after detonation [21–23]. Analytical techniques such as GC–MS and liquid chromatography–mass spectrometry are widely used for identifying organic explosive compounds including TNT, RDX, and PETN [8,12,21–23]. Inorganic oxidizers such as nitrate, chlorate, perchlorate, ammonium, potassium, and sodium ions can be detected using ion chromatography or capillary electrophoresis [8,24].

Studies have demonstrated that physical evidence such as DNA, fingerprints, and trace materials may survive explosive detonations and can be recovered from IED fragments [25–27]. These traces may provide valuable forensic links between the device and individuals involved in its construction.

Nevertheless, the effectiveness of such analyses depends heavily on systematic evidence collection during crime scene investigation. Standardized post-blast investigation protocols emphasize the importance of recovering all device fragments, explosive residues, and associated materials to facilitate accurate forensic reconstruction [6,17,28].

2. Materials and Methods

2.1. Case Background

A bomb was planted at the center of a roadway targeting a VIP during travel with their convoy vehicle. The device was electrically detonated from a distance estimated between **200 and 300 meters**. Illustration of the complete set up is given in Figure 2.

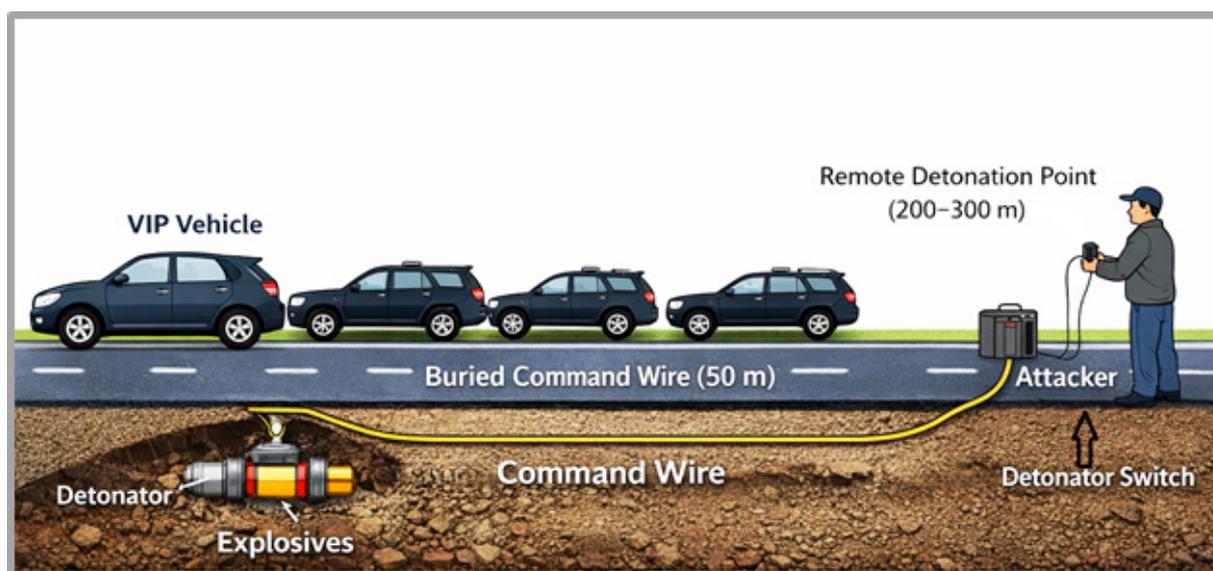


Figure 2: Electrically Initiated IED Configuration and Command-Wire Layout

The case was initially investigated by the local police personals and later it was transferred to a central investigative agency. During investigation:

- A length of electrical wire connected to the device was traced.
- Approximately **50 m of this wire had been deliberately buried beneath the soil surface** extending away from the blast point.
- Only this extended buried portion of wire was recovered and sent for forensic examination.
- No detonator fragments, explosive-bearing debris, or damaged vehicle components were submitted to the

laboratory.

Two exhibits were received for analysis:

Exhibit 1: Questioned electrical wire recovered from the scene

Exhibit 2: Control electrical wire submitted for comparison (Obtained from the nearby shop)

The objective of the forensic examination was to determine whether the questioned wire corresponded to the control sample and to identify any explosive residues associated with the recovered material. The exhibits received were given in the Figure 3.



Figure 3: Questioned Wire and Control wire Submitted for Examination

2.2. Chemical Examination

Preliminary chemical examination of the questioned electrical wire was performed to identify possible traces of explosive residues that may have been deposited during the detonation of explosives. Surface materials were completely extracted using standard solvent extraction procedures commonly employed in post-blast forensic investigations (Ether, Acetone, Water, Sodium Hydroxide and Pyridine). The extracts were subjected to qualitative screening for characteristic components associated with commonly used improvised explosive materials.

The screening targeted the detection of:

- Nitrate-based explosive residues and related inorganic ions
- Nitroaromatic explosive compounds (e.g., TNT and related derivatives)
- Nitramine explosives (e.g., RDX and HMX)
- Oxidizing salts including chlorate and perchlorate residues

These analyses were intended to identify both intact explosive compounds and potential inorganic components associated with improvised explosive formulations [8-13, 21-23, 28-30].

2.3. Thin Layer Chromatography (TLC)

Thin Layer Chromatography (TLC) was employed as a rapid screening technique for the detection of high explosive compounds. Extracted samples were allowed to run on the silica gel TLC plates using appropriate solvent systems selected for the separation of nitroaromatic and nitramine explosives and developed suitably. Chromatographic profiles of the sample extracts were compared with those of certified reference standards to evaluate the possible presence of explosive constituents. Visualization was carried out using suitable detection reagents and UV illumination where applicable [8-13, 21-23, 28-30].

2.4. Gas Chromatography–Mass Spectrometry (GC–MS)

Gas Chromatography–Mass Spectrometry (GC–MS) analysis was conducted as a confirmatory analytical technique for the identification of organic explosive residues. Sample extracts obtained during the solvent extraction procedure were analyzed under optimized GC–MS conditions to detect and characterize:

- organic explosive compounds
- degradation products formed during detonation or environmental exposure
- plasticizers commonly associated with explosive formulations
- binder or additive materials that may be present in commercial or improvised explosive compositions

Mass spectral data were compared with reference spectral libraries and authenticated standards to ensure reliable identification of target compounds [8-13, 21-23, 28-30].

2.5. Physical Examination of Electrical Wires

Comparative physical examination of the questioned and control wires was performed in the Physics Division. In addition to the general examinations—including observations of insulation colour, type of insulation material (PVC, XLPE, rubber, etc.), presence of surface markings or printing on the insulation, number of copper strands forming the conductor, conductor diameter, and wire gauge—the condition of the cut ends was also examined for cut surface characteristics, striation marks, possible tool marks, and surface oxidation patterns. Furthermore, the comparative analysis focused on the following key parameters:

- Copper strand count
- Wire diameter
- Insulation characteristics

Electrical resistance

Microscopic examination was used to observe structural characteristics of the copper conductors and insulation materials.

Electrical resistance measurements were conducted using precision electrical testing equipment to determine whether the two wires exhibited comparable electrical properties.

3. Results

3.1. Explosive Residue Analysis

Chemical analysis performed in the explosives division did not detect the presence of any common explosive ingredients in the questioned exhibit.

No identifiable residues corresponding to common explosive ingredients were observed during instrumental analysis also.

3.2. Physical Comparison of Electrical Wires

Comparative examination of the questioned and control wires revealed significant differences in structural and electrical characteristics.

Key differences included:

- Variation in copper strand count (14 in the questioned wire and 22 in the control wire)

Differences in conductor configuration Differences in electrical resistance values

These observations indicate that the questioned and control wires were not consistent with originating from the same source or manufacturing batch. Summary of the forensic examination is given in the Table 1.

Exhibit	Examination Division	Parameter Examined	Result
Questioned electrical wire	Explosives Division	TNT	Not detected
Questioned electrical wire	Explosives Division	RDX	Not detected
Questioned electrical wire	Explosives Division	PETN	Not detected
Questioned electrical wire	Explosives Division	HMX	Not detected
Questioned electrical wire	Explosives Division	Inorganic ions (Na ⁺ , K ⁺ , NH ₄ ⁺ , NO ₃ ⁻ , etc)	Not detected
Questioned electrical wire	Physics Division	Copper strand count	Different from control sample
Questioned electrical wire	Physics Division	Electrical resistance	Different from control sample
Control electrical wire	Physics Division	Structural characteristics	Not matching questioned sample

Table 1: Summary of Forensic Examination Results

4. Discussion

The forensic interpretation of explosive incidents requires integration of chemical residue analysis, physical examination of device fragments, and contextual information obtained during crime scene investigation. In the present case, the laboratory examination was limited to a segment of electrical wire recovered from the scene and a control wire submitted for comparison.

Chemical examination did not detect the presence of explosive residues on the questioned wire. This observation is consistent with previous studies describing electrically initiated IED systems in which command wires primarily function as conductive elements transmitting electrical current to the detonator [21,24]. When such wires are positioned at a significant distance from the seat of explosion, they may not come into direct contact with explosive materials and therefore may not retain detectable explosive residues after detonation.

Previous experimental and field investigations have demonstrated that the highest concentrations of explosive residues are typically recovered from fragments located near the seat of explosion [21–23]. In contrast, peripheral components such as command wires or remote triggering circuits may contain little or no detectable explosive material.

In the present investigation, the questioned electrical wire was reportedly buried beneath the road surface and extended from the detonation point toward a remote initiation location. Because of its placement away from the immediate blast zone, the absence of detectable explosive

residues on the wire is not unexpected.

The comparative physical examination of the questioned and control wires revealed differences in copper strand count and electrical resistance, indicating that the two wires were not identical. Such structural differences may arise from variations in manufacturing processes, conductor design, or wire gauge characteristics [24]. While these findings allow exclusion of a direct correspondence between the questioned and control samples, they do not provide sufficient information to reconstruct the electrical initiation system of the explosive device.

The absence of additional device components submitted for examination represents a significant limitation in the forensic reconstruction of the incident. Critical materials commonly recovered during post-blast investigations include detonator fragments, battery components, switches, explosive container fragments, and debris from the seat of explosion [6,17,28]. These materials frequently provide the most valuable forensic information regarding explosive composition and device construction.

In cases where such components are not recovered, forensic laboratories may be unable to identify the explosive material used or determine the specific configuration of the initiation system. Similar analytical limitations have been reported in previous forensic investigations involving incomplete debris recovery [18,19]. The present case therefore illustrates the critical importance of systematic and comprehensive crime scene investigation procedures. Standardized post-blast investigation protocols emphasize the use of

controlled search patterns, systematic debris collection, and documentation of the seat of explosion [6,17,28].

Strengthening coordination between crime scene investigators and forensic laboratories can also improve the effectiveness of evidence recovery by ensuring that investigators understand the types of materials required for forensic analysis. Enhanced training programs for investigators involved in explosive incident response may further contribute to improved evidence recovery and more reliable forensic reconstruction of explosive events.

4.1. Forensic Implications for Crime Scene Investigation

The present case study demonstrates the critical importance of systematic evidence recovery during post-blast crime scene investigations. In explosive incidents, the detonation process frequently destroys or disperses components of the improvised explosive device (IED), resulting in fragmentation of the device and widespread distribution of debris across the surrounding area. The expected distribution pattern of the debris is illustrated in the Figure 4. Consequently, the success of forensic reconstruction depends heavily on the careful recognition, recovery, and preservation of all relevant materials during the initial crime scene examination [2,16].

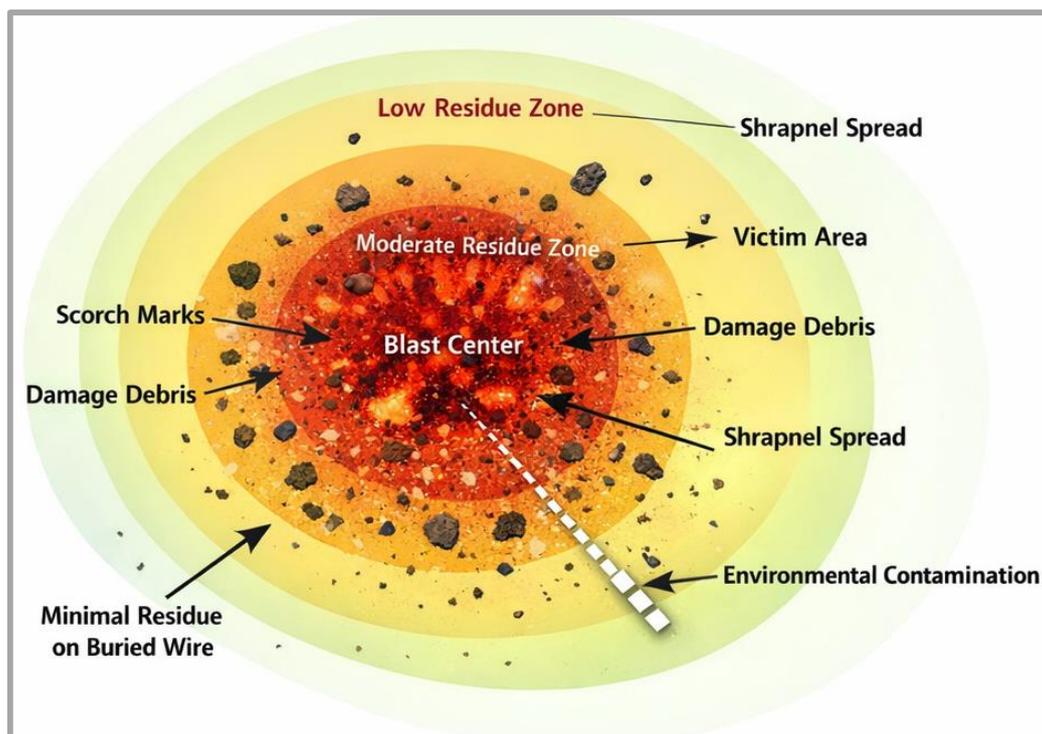


Figure 4: Expected Distribution Pattern of Explosive Residues Following Detonation

In electrically initiated IEDs, several components may provide important forensic information, including the detonator, power source, switching mechanism, connecting wires, and fragments of the explosive container. Among these, detonator fragments and debris located near the seat of explosion often contain the highest concentration of explosive residues and may allow identification of the explosive composition used [7,10,21]. Failure to recover these components can significantly reduce the ability of forensic laboratories to determine the nature of the explosive material involved.

In the present investigation, the only exhibit recovered from the scene was a segment of electrical wire believed to have been used as the command wire for detonation. Because the wire had been buried beneath the road surface at a considerable distance from the seat of explosion, it did not contain detectable explosive residues. As a result, chemical examination did not provide information regarding the explosive composition used in the device.

Furthermore, the absence of additional device components

prevented reconstruction of the initiation system and limited the ability to establish forensic linkage between the recovered evidence and suspected materials. Similar limitations have been reported in previous studies of post-blast investigations where incomplete debris recovery significantly restricted forensic interpretation [17,19].

The findings of this case therefore highlight the importance of applying standardized post-blast investigation procedures. Such procedures include systematic grid-based debris collection, documentation of the seat of explosion, recovery of detonator fragments, and preservation of potential explosive residue samples [6,11,17].

Improved coordination between crime scene investigators and forensic laboratories can also enhance the effectiveness of evidence recovery by ensuring that investigators are aware of the types of materials required for laboratory analysis.

4.2. Limitations of the Study

The present study is based on the forensic examination of a

limited number of exhibits recovered from a single explosive incident. As only one segment of electrical wire and a control sample were submitted for examination, the scope of

forensic analysis was inherently restricted. The limitations in forensic reconstruction are summarized in Table 2.

Device Component	Forensic Value	Recovered in Case
Explosive residues	Identification of explosive composition	No
Detonator fragments	Initiation mechanism identification	No
Container fragments	Device construction reconstruction	No
Command wire	Electrical initiation pathway	Yes
Power source fragments	Triggering system reconstruction	No

Table 2: Evidence Recovered vs. Evidence Required for Complete Forensic Reconstruction

The absence of additional device components, including detonator fragments, explosive residues from the seat of explosion, and fragments of the explosive container, significantly limited the ability to reconstruct the device configuration or identify the explosive composition used. Consequently, the findings of this study primarily highlight the analytical limitations associated with incomplete evidence recovery rather than providing a comprehensive reconstruction of the explosive device.

Another limitation arises from the environmental conditions associated with post-blast crime scenes. Factors such as heat, pressure, and environmental exposure may degrade explosive residues or disperse device fragments over large areas, complicating evidence recovery and interpretation [7,10,21].

Despite these limitations, the case provides valuable insight into the forensic consequences of incomplete crime scene evidence collection. The findings underscore the need for improved training and standardized procedures for post-blast investigation to ensure that critical evidence is systematically recovered and preserved.

Future research may focus on developing improved protocols for post-blast evidence recovery and exploring analytical techniques capable of detecting ultra-trace explosive residues on device components located at greater distances from the seat of explosion.

5. Conclusion

The forensic investigation of improvised explosive device incidents relies fundamentally on the systematic recovery and scientific examination of evidence from the crime scene. The present case study demonstrates how incomplete evidence recovery can significantly limit the scope of forensic interpretation and prevent comprehensive reconstruction of an explosive device.

Although laboratory analysis confirmed that the questioned electrical wire did not match the control sample and did not contain detectable explosive residues, the absence of critical device components—including detonator fragments, explosive-bearing debris, and container fragments—prevented identification of the explosive composition and

reconstruction of the device architecture.

These findings emphasize that the reliability of forensic conclusions in explosive investigations is closely linked to the completeness of evidence collected during crime scene examination. Failure to recover essential device components may lead to analytical constraints that limit the ability of forensic laboratories to provide definitive investigative conclusions.

Strengthening post-blast crime scene investigation procedures through improved training, standardized evidence recovery protocols, and closer collaboration between investigators and forensic laboratories will significantly enhance the effectiveness of forensic reconstruction in explosive-related cases.

Ultimately, comprehensive evidence recovery remains one of the most critical factors influencing the success of forensic attribution in improvised explosive device investigations.

Declarations

Ethics Approval and Consent to Participate

Not applicable

Consent for Publication

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Author Contributions

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formal analysis, D.K. & T.R. investigation, D.K. & T.R. writing—original draft preparation, D.K. writing—review and editing, D.K. visualization, D.K. and supervision, D.K. & T.R. The authors have read and agreed to the published version of this manuscript.

Institutional Review Board Statement

Not applicable.

Data Availability Statement

The authors declare that the data supporting the findings of this study are available within the paper. Should any raw data files be needed in another format, they are available from the author upon reasonable request.

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Conflicts of Interest

The authors declare that there is no conflicts of interest.

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