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A Critical Examination of GIS Applications in Forensic Science and the Security Implications of Publicly Accessible 3D Data

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Abstract: ***Geographic Information Systems (GIS) have revolutionized forensic science by enabling advanced spatial analysis, high-fidelity 3D crime scene reconstruction, and precise hotspot mapping. This research critically examines the "dual-use" nature of these technologies, balancing their investigative benefits against the escalating security risks posed by publicly accessible high-resolution 3D geospatial data. Utilizing a qualitative and comparative methodology, the study evaluates prominent platforms—including Google Earth, ArcGIS Pro, GeoWGS84.ai, NASA Worldview, and Zoom Earth—to assess their forensic utility versus their potential for criminal exploitation. The findings reveal that while geomatic tools like Terrestrial Laser Scanning (TLS), UAVs, and Ground Penetrating Radar (GPR) enhance evidence documentation and subsurface anomaly detection, the democratization of 10-cm to 16-cm resolution imagery allows both state and non-state actors to acquire detailed digital schematics of sensitive infrastructure. The research identifies critical vulnerabilities, such as "asymmetric reconnaissance" and the total absence of access controls on near real-time monitoring platforms, which can be weaponized for digital blueprints, infrastructure targeting, and cyber-physical attacks. Furthermore, the study highlights significant technical backlogs, including a lack of redaction mechanisms, the absence of universal security protocols for forensic data, and insufficient governance frameworks for commercial satellite tasking. The paper concludes with urgent recommendations for standardized encryption and "shutter control" protocols to mitigate the erosion of spatial privacy and protect national security without stifling forensic innovation.***

Keywords: 3D Scene Reconstruction,Critical Infrastructure Protection, Forensic GIS, Geospatial Intelligence (GEOINT), Synthetic Aperture Radar (SAR), Technical Backlog.

I. INTRODUCTION

The integration of GIS into forensic science has revolutionized modern policing these advanced platforms now combine various data sources to perform complex spatial analysis and create detailed 3D reconstructions. By leveraging this technology, law enforcement agencies can better visualize spatial patterns, identify hotspots, and reconstruct crime scenes to improve investigative outcomes [1], [2], [3].

Modern forensic GIS utilizes advanced technologies—such as terrestrial laser scanning, UAVs, Ground Penetrating Radar, and Structure from Motion (SfM) algorithms—to capture and analyze crime scene data [4], [18]. The evolution from 2D mapping to 3D environments is driven by advancements in remote sensing and computational power. By 2026, the landscape includes cloud-native platforms like Cesium and AI-driven engines like GeoWGS84.ai [7].

These tools generate high-density 3D point cloud models, enabling investigators to document evidence, analyze bloodstains, and simulate human movement within virtual environments. These immersive reconstructions allow for continued forensic examination and courtroom presentations long after the physical scene is released [19], [20]. However, publicly accessible high-resolution 3D data poses significant security risks, potentially serving as digital blueprints for criminal reconnaissance or infrastructure attacks. Integrating these models with real-time tracking data creates vulnerabilities that can be exploited for hijacking, kidnapping, or targeted theft [21], [22].

A. Forensic GIS Applications

Spatial Targeting and Search Area Reduction GIS streamline forensic investigations by systematically narrowing search parameters for clandestine graves or missing persons. Using techniques like viewshed analysis and probability mapping, GIS integrates environmental datasets to prioritize high-probability search locations [5].

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Crime Mapping and Hotspot Analysis Crime mapping utilizes GIS to detect "hotspots"—geographic concentrations of criminal activity [6]. This allows law enforcement to identify spatial patterns and analyze the relationships between specific crimes and environmental factors.

3D Scene Capture and Documentation Terrestrial laser scanning and photogrammetry rapidly capture high-detail 3D scene geometry. These methods create permanent, accurate digital records, enabling investigators and legal officials to analyze scenes long after the physical location has been released.

B. Publicly Accessible 3D GIS Platforms

These platforms serve a broad user base, from software developers to forensic analysts conducting granular spatial investigations [7].

GeoWGS84.ai: AI-Driven Intelligence GeoWGS84.ai uses machine learning to automate the detection of landscape anomalies, such as ground disturbances. In forensics, automated satellite updates provide real-time intelligence on physical changes, offering critical evidence of illegal activities.

Google Earth: Forensic Utility vs. Global Exposure Google Earth is a vital pre-exploration tool for familiarizing investigators with access points and landmarks [7]. Its forensic value is enhanced by historical archives and GNSS data integration [8, 9]. However, its "global panopticon" nature presents risks; high-resolution imagery of sensitive buildings provides adversaries with the same spatial and temporal intelligence once restricted to official agencies [14, 15, 8, 9].

C. ArcGIS Pro and QGIS: The Industry Standards

ArcGIS Pro and QGIS are the de facto standards for professional GIS analysis, often used together to create probability maps and viewshed analyses.

ArcGIS Pro: A commercial platform offering extensive 3D modelling and "secure mapping" environments [10],[12]. However, geographic profiling within these systems can lead to false inferences in atypical or single-crime investigations [9]. Furthermore, integrated geolocation datasets risk exposing sensitive personal information if data governance is not stringently enforced [11].

QGIS: A powerful, cost-effective open-source alternative. Its transparency and flexible plugin architecture allow for high customization in specialized forensic analysis.

D. NASA Worldview and Zoom Earth: Real-Time Vulnerabilities

These platforms prioritize near real-time data; NASA Worldview offers over 1,200 satellite products, with geostationary imagery updating as frequently as every 10 minutes [16]. Security Implications: While designed for environmental monitoring, their measurement tools can be exploited to calculate tactical requirements for illicit activities [16]. Significantly, the primary security vulnerability of both applications is the complete absence of access controls, making sensitive near-real-time data available to any user [17].

Other 3D Platforms

Additional tools such as GRASS GIS, GeoServer, and Carto provide further specialized capabilities for hosting and analyzing 3D geospatial data, contributing to an increasingly accessible landscape of high-resolution spatial intelligence.

II. METHODOLOGY

A. Research Objectives

This study employs a qualitative and comparative methodology to analyze the dual nature of Geographic Information Systems (GIS) in forensic science. The specific objectives are:

- To examine the forensic applications of 3D Geospatial Intelligence Systems in criminal investigations.
- To critically evaluate the security risks and potential for criminal exploitation inherent in publicly accessible 3D geospatial platforms.

Statement of the ProblemGeospatial intelligence has revolutionized crime investigation through 3D mapping and environmental monitoring, but high-resolution public data creates significant security vulnerabilities. Criminals can exploit these tools to scout and target critical infrastructure. Despite its forensic value, research connecting investigative utility with security risks is sparse; this study fills that gap by analyzing platform benefits alongside accessibility risks

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Need and Significance of the StudyModern forensics increasingly relies on digital spatial analysis for evidence interpretation. While GIS facilitates crime scene visualization and pattern detection, it simultaneously exposes sensitive infrastructure. This study addresses the "dual-use" nature of GIS—balancing investigative advantages with cybersecurity risks—to develop frameworks for its secure and responsible application in forensic science.

Research Approach and DesignThis study utilizes a qualitative, comparative framework to evaluate the forensic utility and security vulnerabilities of selected geospatial platforms. By assessing analytical capabilities, accessibility, and visualization fidelity, the research examines how these tools enhance crime analysis while investigating the risks inherent in public geospatial data

B. Literature Search Strategy

A comprehensive literature review was executed across major scholarly databases, including Google Scholar, ResearchGate, ArXiv, DOAJ, and PubMed. The search encompassed over 200 research publications spanning the fields of Geographic Information Systems (GIS), geospatial intelligence, forensic science, and cybersecurity. Studies were selected based on their specific contributions to GIS-driven criminal investigations and the security implications of emerging geospatial technologies.

C. Data Collection

The study is based on **secondary data sources**. Information was collected from peer-reviewed journal articles, conference papers, research reports, and technical documentation related to GIS software and geospatial intelligence systems. These sources provide detailed insights into the capabilities of geospatial platforms and their applications in forensic investigations.

D. Security Risk Assessment

The study also examines the potential **security risks associated with publicly accessible geospatial platforms**. High-resolution satellite images, detailed geographic data, and live environmental monitoring tools may be exploited for reconnaissance or targeting critical infrastructure. The research analyses possible vulnerabilities related to data privacy, information exposure, and cybersecurity threats associated with geospatial technologies.

E. Data Collection and Analysis Phases

The data collection and analysis process was conducted in the following phases:

- Phase 1: Literature Collection: Gathered scholarly data on GIS, geospatial intelligence, and forensics from academic databases.
- Phase 2: Platform Selection: Selected Google Earth, ArcGIS Pro, QGIS, NASA Worldview, Bing Maps, and Zoom Earth based on accessibility and function.
- Phase 3: Data Extraction: Documented key features, including spatial visualization, satellite imagery, and analytical tools.
- Phase 4: Comparative Analysis: Evaluated platforms for their capabilities in 3D mapping, spatial visualization, and environmental monitoring.
- Phase 5: Forensic Assessment: Examined platform utility in crime scene analysis, spatial mapping, and environmental observation.
- Phase 6: Security Risk Analysis:Analyzed potential vulnerabilities and misuse risks associated with public geospatial data.
- Phase 7: Interpretation: Evaluated the intersection of forensic utility and security implications based on combined findings.

F. Ethical Considerations

This research adheres to ethical standards by utilizing only open-access datasets and public geospatial platforms. No classified, confidential, or personal identification data was accessed. The study focuses strictly on analyzing technological capabilities and security risks through the responsible use of public information.

G. Limitations of the Study

This study primarily evaluates secondary data and publicly accessible platforms, which may not reflect the specialized geospatial systems used by government or military agencies. Analysis is limited to selected tools, including Google Earth, ArcGIS Pro, QGIS, NASA Worldview, and Zoom Earth; other technologies may present different capabilities. Future research should incorporate experimental analysis and case studies to further validate these forensic applications.

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H. Platform-Specific Security Analysis

Google Earth: Forensic Utility vs. Global Exposure

Google Earth offers forensic utility via historical imagery and GNSS integration for scene reconstruction [8], [9]. However, its "global panopticon" nature enables unimpeded virtual access to private or restricted spaces, creating significant exposure risks through high-resolution building and rooftop data [14], [15]. Crucially, this ubiquity eliminates investigator exclusivity, granting adversaries the same spatial and temporal intelligence once restricted to official agencies [8], [9].

ArcGIS and Professional GIS Frameworks

ArcGIS is the industry standard for structured forensic case management and spatial analysis [10], [12]. Despite providing "secure mapping" for agencies, it presents methodological and privacy challenges; specifically, geographic profiling and predictive analytics can yield false inferences in atypical or isolated cases [9]. Additionally, integrating diverse geolocation datasets risks exposing sensitive personal information if data governance is not strictly enforced [11].

NASA Worldview and Zoom Earth: Real-Time Monitoring

NASA Worldview and Zoom Earth prioritize near real-time data acquisition, offering over 1,200 satellite products—some accessible within hours—and geostationary updates every 10 minutes [16].

While designed for environmental monitoring, their built-in distance and area measurement tools can be exploited to calculate tactical requirements for illicit activities [16]. The primary security vulnerability for both platforms is the total absence of access controls, enabling unrestricted global monitoring [17].

III. RESULT AND DISCUSSION

The investigation into 3D GEOINT's role in crime investigation yielded several key findings regarding technological integration and analytical capabilities.

A. Advanced Crime Scene Documentation Tools

The research identifies a suite of geomatic tools used to transform physical scenes into high-fidelity digital models:

- Terrestrial Laser Scanning (TLS) & Photogrammetry: Generates dense 3D point cloud models for precise evidence mapping and bloodstain pattern analysis.
- Ground Penetrating Radar (GPR): Integrated with GIS to map subsurface anomalies, such as clandestine burials or hidden weapon caches, in 3D [13].
- Unmanned Aerial Vehicles (UAVs): Provide high-resolution orthomosaics and 3D terrain models for tactical intelligence and search area determination.

B. Spatial Analytical Techniques

GIS-based spatial analysis significantly reduces search time and increases investigative accuracy:

- Probability Mapping: Merges hydrological, geological, and topographic data to prioritize search areas for human remains or missing persons.
- Geographic Profiling: Utilizes spatial algorithms to identify patterns in serial crimes and hypothesize an offender’s "anchor point" or residence [14].

C. Security Risks and Criminal Exploitation

Evaluation of public 3D platforms revealed significant security gaps and exploitation vectors threatening privacy and infrastructure.

1) The Democratization of High-Resolution Intelligence Data indicates a shift from government-controlled surveillance to a commercial "global panopticon":

- Resolution Thresholds: Imagery with 10-cm and 16-cm resolution is commercially available, allowing for the identification of individual building features and rooftops [15].
- Satellite Statistics (2024-2026): Of 472 Earth observation satellites identified, private operators control 270, outnumbering government units (202), which complicates data governance [15].
- RF Monitoring: Commercial satellites can monitor Radio Frequency (RF) signals from radars and handheld radios, potentially allowing adversaries to track security force movements.

2) Criminal Exploitation Vectors The research identifies three primary ways 3D platforms are "weaponized" by criminal actors:

- Digital Blueprints for Reconnaissance: 3D urban models serve as schematics for planning heists, identifying CCTV blind spots, and scouting routes without a physical presence [16].
- Infrastructure Targeting: Unvetted access to detailed 3D imagery of power grids and government sites facilitates the planning of sabotage or "cyber-physical" attacks.
- Near Real-Time Tracking: Platforms like NASA Worldview provide geostationary updates as frequently as every 10 minutes, enabling the monitoring of tactical assets [17]

D. Comparative Evaluation of 3D Geospatial Platforms

The following table summarizes the forensic utility versus the security risk profiles of the major platforms evaluated in this study:

Table 4.1 Summary of forensic utility versus the security risk profiles

Platform	ForensicPrimary use	Security risk factor	Accessibility
GeoWGS84.ai	Ai anomaly Burial detection	Automated Reconnaissance	Professional/Proprietary
Google Earth	Scene familiarization and GNSS import	High-resisted exposure	Public / Free
ArcGIS Pro	Case-management and 3D modelling	Privacy/data governance	Professional /paid
NASA Worldview	Environmental monitoring	Real-time surveillance	Public / Free
Zoom Earth	Tactical requirements calculation	Lack of redaction/shutter control	Public / Free
Cesium	City-scale 3D streaming	Unauthorized digital schematics	Open Source / Web

E. Technical Backlogs and Governance Gaps

Lack of Redaction: Public platforms (NASA Worldview, Zoom Earth) provide no mechanism for redacting sensitive national security imagery (NASA Earthdata, 2026).

Standardization Gap: There are no universal security protocols for the encryption or sharing of 3D forensic data across law enforcement jurisdictions.

Governance Deficiency: Data governance frameworks are insufficient to manage the commercial tasking of high-resolution satellites by non-state actors.

F. Discussion

The "Global Panopticon" and the Erosion of Spatial PrivacyThe proliferation of high-fidelity 3D geospatial data represents a total erosion of spatial privacy for the average citizen. When detailed 3D models of private residences and yards are accessible via platforms like Google Earth, the "sacred space" of the home is effectively transformed into a public schematic [8]. Current research suggests that legal frameworks have failed to keep pace with this "high-altitude intrusion," leaving individuals vulnerable to both state and non-state surveillance.

Democratized Intelligence: The Adversarial AdvantagePerhaps the most significant security implication is the levelling of the playing field" between law enforcement and criminal actors.

- Asymmetric Reconnaissance: Historically, geospatial intelligence was a state monopoly. Today, the democratization of technology allows criminal organizations to "task" private satellites or use free platforms like NASA Worldview for near real-time monitoring. This creates an environment of "asymmetric reconnaissance," enabling adversaries to identify entry points, perimeter weaknesses, and surveillance blind spots without triggering a physical security response.
- The "Cyber-Physical" Threat: This research identifies a new class of crime where digital reconnaissance on 3D platforms serves as the primary enabler for physical attacks [13]. Whether planning a heist via virtual 3D building models or facilitating high-value kidnappings through real-time location tiles, the digital-to-physical threat vector has become a critical security concern [8]

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The Regulatory and Technical Backlog

- The Failure of Shutter Control: Public platforms often lack the "shutter control" protocols used by military systems to redact sensitive imagery during crises. Consequently, critical infrastructure—ranging from power grids to command centers—is permanently "broadcast" in high resolution to any global observer.
- The Standardization Gap: There is a conspicuous lack of standardized security protocols for forensic GIS data. This deficiency increases the risk of "forensic data hijacking" and unauthorized access to sensitive case files. Without secure, standardized frameworks to manage these datasets, the integrity of forensic investigations remains compromised

IV. CONCLUSION

While GIS and 3D geospatial platforms offer revolutionary potential for forensic reconstruction and criminal investigation, their public accessibility creates significant security vulnerabilities. The transition of high-resolution spatial intelligence from restricted government use to the public domain enables both state and non-state actors to exploit sensitive infrastructure. To mitigate these risks, the "global panopticon" effect must be balanced with stringent data governance and access control policies. Future forensic progress depends on utilizing these powerful spatial tools while proactively addressing the digital schematics they provide to potential adversaries.

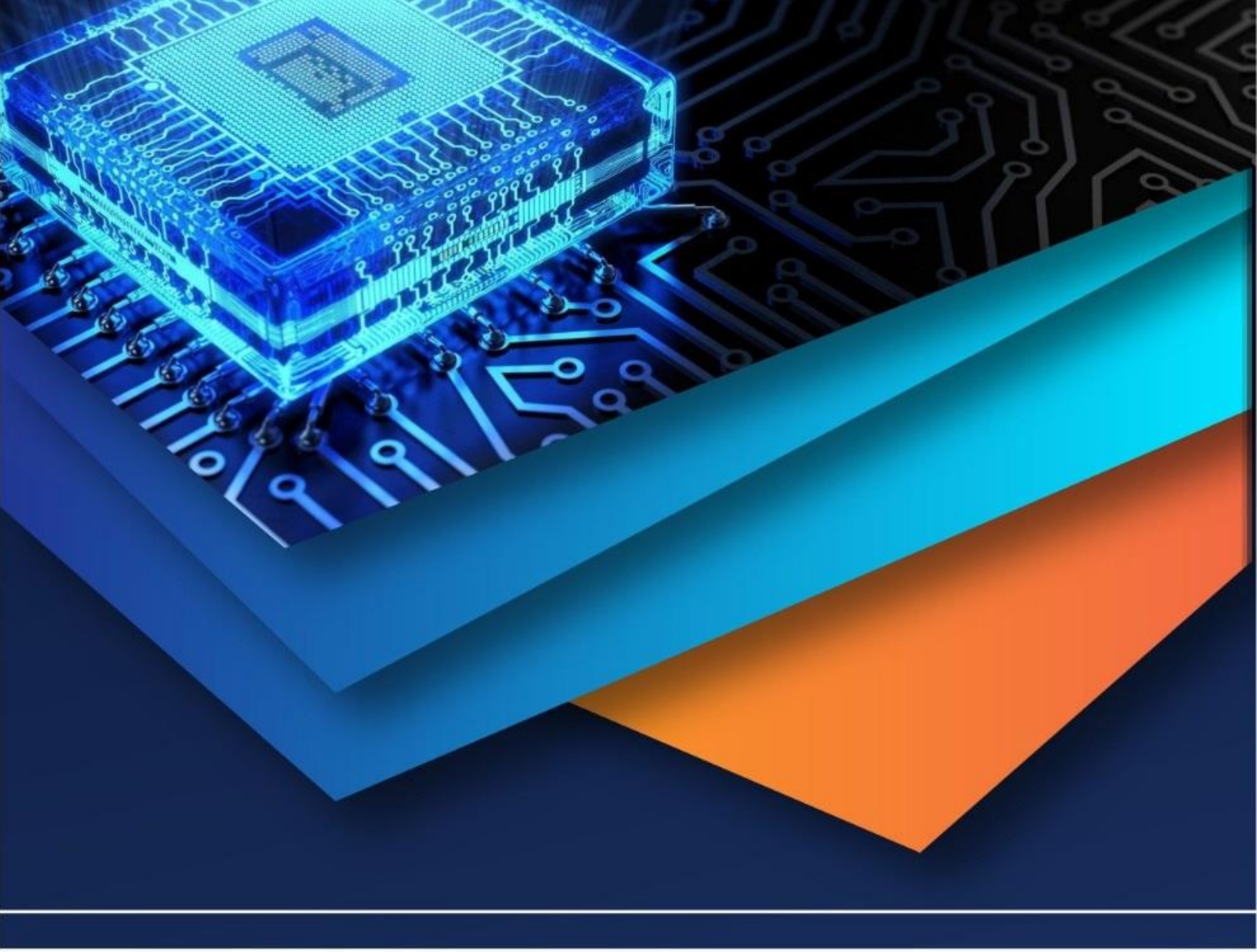
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