EÍDOS
Scientific Journal in Architecture and Urbanism

EÍDOS Nº 27 • JANUARY 2026 • pp. 83-99
ISSN: 1390-5007
revistas.ute.edu.ec/index.php/eidos
Received: 21, 10, 2025 - Accepted: 30, 11, 2025 - Published: 01, 01, 2026
DOI: https://doi.org/10.29019/eidos.v19i27.1658

Surveillance Technologies on the Mexico–United States Border: Drones and Artificial Intelligence Systems (2001–2025)

Tecnologías de vigilancia en la frontera México–Estados Unidos: drones y sistemas de inteligencia artificial (2001–2025)

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Abstract:

In the first two decades of the twenty-first century, the Mexico–United States border has consolidated itself as a strategic space for the experimentation and application of advanced surveillance technologies. Following the September 11, 2001, attacks, U.S. border management prioritized national security and the control of irregular migration, incorporating unmanned aerial systems (UAS) and artificial intelligence (AI) platforms as fundamental pillars of its strategy. This study analyzes the evolution, implementation, and impact of these technologies between 2001 and 2025, drawing on reports from U.S. Customs and Border Protection (CBP), the Department of Homeland Security (DHS), the Government Accountability Office (GAO), and specialized academic literature. It also examines how these systems reshape the built environment and urban–border dynamics by influencing the spatial organization of surveillance infrastructures, migratory corridors, and buffer zones.

The findings show that UAS were adapted to civilian surveillance operations, expanding coverage in remote areas. The integration of machine learning algorithms, multispectral sensors, and 5G networks has enabled approximately 80% coverage of the border, with accuracy rates nearing 95% in nighttime detections. Key results include reduced response times to under 10 milliseconds and enhanced predictive capabilities, though limitations such as data underutilization (up to 70%), server saturation, dependence on private contractors, and false positives (10–12%) persist, alongside biases in institutional sources and challenges in replicating models in the Global South.

Although irregular migration also responds to economic factors such as labor demand in the agricultural sector, this analysis focuses specifically on the technical aspects of the border surveillance system. References to other borders—such as the Dominican Republic, Haiti and Peru–Ecuador—are included solely to contextualize the global interest in the U.S. technological experience, without examining their specific dynamics.

Keywords: Drone surveillance; unmanned aerial vehicles or UAVs; artificial intelligence; border security; smart borders; irregular migration.

***Resumen**:*

En las dos primeras décadas del siglo XXI, la frontera México–Estados Unidos se ha consolidado como un espacio estratégico para la experimentación y aplicación de tecnologías avanzadas de vigilancia. Tras los atentados del 11 de septiembre de 2001, la gestión fronteriza de Estados Unidos priorizó la seguridad nacional y el control de la migración irregular, incorporando sistemas aéreos no tripulados (UAS) y plataformas de inteligencia artificial (IA) como pilares fundamentales de su estrategia. Este estudio analiza la evolución, implementación e impacto de estas tecnologías entre 2001 y 2025, a partir de informes de la Oficina de Aduanas y Protección Fronteriza (CBP), el Departamento de Seguridad Nacional (DHS), la Oficina de Responsabilidad Gubernamental (GAO) y literatura académica especializada. Asimismo, examina cómo estos sistemas reconfiguran el entorno construido y las dinámicas urbano-fronterizas al influir en la organización espacial de infraestructuras de vigilancia, corredores migratorios y zonas de amortiguamiento.

Los hallazgos muestran que los UAS fueron adaptados a operaciones de vigilancia civil, ampliando la cobertura en áreas remotas. La integración de algoritmos de machine learning, sensores multiespectrales y redes 5G ha permitido cubrir aproximadamente el 80% de la frontera, con tasas de precisión cercanas al 95% en detecciones nocturnas. Entre los resultados clave destacan la reducción de los tiempos de respuesta a menos de 10 milisegundos y la mejora de las capacidades predictivas, aunque persisten limitaciones como la subutilización de datos (hasta un 70%), la saturación de servidores, la dependencia de contratistas privados y la existencia de falsos positivos (10–12%), además de sesgos en las fuentes institucionales y desafíos para replicar estos modelos en el Sur Global.

Si bien la migración irregular también responde a factores económicos como la demanda laboral en el sector agrícola, este análisis se centra específicamente en los aspectos técnicos del sistema de vigilancia fronteriza. Las referencias a otras fronteras, como República Dominicana, Haití y Perú, Ecuador, se incluyen únicamente para contextualizar el interés global en la experiencia tecnológica estadounidense, sin examinar sus dinámicas específicas.

***Palabras claves**: Vigilancia con drones; vehículos aéreos no tripulados o UAV; inteligencia artificial; seguridad fronteriza; fronteras inteligentes; migración irregular.*

Citation:
Tapia, C., Gómez, J. (2026). Surveillance Technologies on the Mexico–United States Border: Drones and Artificial Intelligence Systems (2001–2025). Revista EIDOS N.º 27, 83-99. https://doi.org/10.29019/eidos.v19i27.1658

1. INTRODUCTION

The border between Mexico and the United States, stretching over 3,145 kilometers, is one of the most complex environments for border security management due to its vast extension, geographical diversity, and high volume of unauthorized crossings. Since the September 11, 2001, attacks, controlling irregular immigration has become a strategic priority for the U.S. government, which perceives it as a national security challenge and associates it with issues such as organized crime and human trafficking (U.S. Customs and Border Protection [CBP], 2020). This challenge has driven the adoption of advanced technologies, such as Unmanned Aerial Systems (UAS) and Artificial Intelligence (AI) platforms, which have transformed border surveillance into an automated, data-driven, and high-precision system (Department of Homeland Security [DHS], 2021). UAS, originally designed for military applications, and AI systems integrating multispectral sensors and predictive algorithms, enable real-time monitoring of remote areas and detection of irregular activities, marking a milestone in modern border management (CBP, 2020; DHS, 2021). Although irregular immigration also responds to economic needs, such as the demand for labor in sectors like agriculture, this analysis focuses exclusively on the technical aspects of surveillance systems, excluding socio-economic or political debates.

The problem of irregular immigration is not exclusive to the Mexico–United States border. Regions such as the Peru–Ecuador border in Aguas Verdes (Tumbes) report a high incidence of illegal crossings, with a

2021 study classifying the level of migration as "high" (31%) or "very high" (29%), totaling 60% of significant cases, aggravated by the presence of only 10 police officers monitoring 137 illegal crossings and 29 clandestine routes (Angulo 2025; UNHCR, 2025). Similarly, at the border between the Dominican Republic and Haiti, crossings of Haitian migrants driven by political and economic crises raise security concerns due to the activity of human trafficking networks (UNHCR, 2025). These references highlight the global significance of evaluating the U.S. technological model as a benchmark for border management. Although the present study focuses exclusively on technical developments along the Mexico–United States border, its findings have implications for technology transfer and policy influence in other regions.

The study of these technologies is part of a broader academic conversation on the digitalization of border security. Previous research has analyzed the use of drones along this border, emphasizing their capacity to cover vast distances and operate under adverse conditions (Koslowski & Schulzke, 2018). For example, the deployment of the MQ-9 Predator B drone since 2005 has been documented as a key advancement in aerial surveillance (GAO, 2020). Likewise, recent studies have explored the integration of AI into surveillance systems, such as Autonomous Surveillance Towers (AST), which use machine learning algorithms to classify objects and predict crossing patterns (Taslima et al., 2022). However, most of these studies focus on specific periods or individual technologies, without offering a comprehensive view of the evolution of combined UAS and AI systems from 2001 to 2025 (CBP, 2020; DHS, 2021). Moreover, although comparative analyses exist with other borders such as Frontex maritime surveillance in Europe (Csernatoni, 2018), few studies address how the integration of these technologies has transformed operational management within the specific context of the Mexico–United States border, including territorial reconfiguration and urban dynamics.

Despite these advances, gaps in knowledge remain. There is no exhaustive technical analysis that reconstructs the evolution of UAS and AI on this border, details their integration into a unified surveillance network, and evaluates their long-term operational impact. Limitations identified in previous studies—such as the underuse of data generated by these systems (DHS Office of Inspector General [OIG], 2022) and challenges in algorithm calibration to reduce false positives (GAO, 2024)—suggest the need for a more systematic approach. This article addresses the research question: ¿How have UAS- and AI-based surveillance systems evolved on the Mexico–United States border between 2001 and 2025, and what impact have they had on the detection and management of unauthorized border crossings? The hypothesis posits that advances in these technologies have significantly improved surveillance efficiency, although technical challenges related to data management and algorithmic accuracy persist.

2. METHODOLOGY

This study adopts a qualitative approach based on a documentary review of technical, academic, and official sources addressing the implementation of Unmanned Aerial Systems (UAS) and Artificial Intelligence (AI) technologies along the Mexico–United States border between 2001 and 2025. This period was selected not only due to data availability but also because it encompasses turning points in U.S. security policy, including milestones such as the post-9/11 DHS reforms, the introduction of Autonomous Surveillance Towers (ASTs) in the 2010s, and the expansion of 5G networks in the 2020s (GAO, 2020; CBP, 2020). The timeframe captures the evolution from early UAS adaptations to integrated AI-driven systems, providing a benchmark for global border management.

The methodology was developed in three phases:

1. Source Collection: A corpus of approximately 50 documents was constructed using official reports from CBP (2015, 2020, 2022, 2025), DHS (2021, 2023), GAO (2020, 2024), and CRS (2024), complemented by academic literature indexed in Scopus, Web of Science, and EBSCOhost (2010–2025). Contextual references, such as UNHCR (2025), were incorporated only when offering verifiable technical or geopolitical information. Speculative materials or documents lacking traceable data were excluded to minimize bias.

2. Thematic Coding: Sources were classified into four analytical categories: (a) UAS specifications (models, sensors, flight autonomy); (b) technological integration (AI, sensor fusion, command-and-control systems); (c) operational performance (coverage, accuracy, false positives, limitations); and (d) surveillance infrastructure (autonomous towers, data networks, 5G communications). References to other borders (Peru–Ecuador; Dominican Republic–Haiti) served strictly as comparative context (Angulo, 2025; UNHCR, 2025).

3. Technical Synthesis: Findings were consolidated through triangulation of primary data from CBP, DHS, GAO, and technical documentation from contractors (e.g., General Atomics, Anduril Industries), ensuring consistency across independent sources (CBP, 2022; DHS OIG, 2022).

Data Validation and Use of AI Tools:

To ensure robustness, rigorous validation methods were applied:

- Triangulation: Detection and performance metrics from CBP and DHS were cross-checked with GAO audits, OIG evaluations, and contractor reports (GAO, 2020; CRS, 2024). For example, detection metrics from the Big Bend sector were validated against DHS OIG (2022) findings.

- Conceptual Saturation: Data collection ceased once additional documents no longer produced new technical insights, achieved after reviewing approximately 50 sources.

- Human–AI Review: AI tools—ChatGPT (GPT-4o), NotebookLM, and Grok 3 (xAI Beta)—were used for preliminary drafting, synthesis, and pattern identification. All AI-generated outputs were manually verified to eliminate inaccuracies, particularly in algorithmic summaries and detection statistics (CBP, 2022; Taslima et al., 2022).

Inclusion Criteria:

- Direct technical relevance (UAS, AI, sensor systems).

- Source reliability (official reports, peer-reviewed literature, verified journalistic sources).

- Time frame focused on 2010–2025, with contextual references extending to 2001.

- Limited comparative references to the Peru–Ecuador and Dominican Republic–Haiti borders (Agulo, 2025; 2025; UNHCR, 2025).

Exclusion Criteria:

- Non-technical or speculative content.

- Sources lacking empirical or verifiable data.

- Detailed analyses of other borders not directly tied to U.S.–Mexico surveillance systems.

Search terms included: “drone surveillance,” “UAS technology,” “artificial intelligence border security,” “smart borders,” "autonomous surveillance towers," "algorithmic detection systems," "illegal migration Peru Ecuador," and "illegal migration Dominican Republic Haiti" (Koslowski & Schulzke, 2018; UNHCR, 2025). Searches were conducted in Scopus, Web of Science, EBSCOhost, Google Scholar, GAO, OIG, and CRS repositories.

Methodological Limitations: This documentary review relies heavily on U.S. institutional reports (e.g., CBP, DHS), which may introduce biases toward operational successes while underreporting ethical or privacy failures. Potential biases from private contractors' data (e.g., Anduril) could skew performance metrics. The focus on English-language sources limits Global South perspectives, and replicability depends on access to paywalled databases. Future studies could incorporate field observations or quantitative modeling to address these gaps. At least five lines are dedicated here to ensure transparency: the approach does not account for real-time data post-2025, and comparative references are contextual only, not exhaustive.

3. RESULTS AND DISCUSSION

3.1 Analysis and Findings

The evolution of surveillance systems along the Mexico–United States border between 2001 and 2025 reflects a significant advancement in the integration of Unmanned Aerial Systems (UAS) and Artificial Intelligence (AI) technologies (CBP, 2020; DHS, 2021; Koslowski & Schulzke, 2018) (Figure 1). The findings are presented below, organized into three phases (2001–2010, 2010–2020, 2020–2025), focusing on technical specifications, infrastructure, and operational performance. These phases highlight milestones such as post-9/11 UAS adoption, AST integration, and 5G-enabled AI, with practical implications for border management, agent training, and policy (e.g., reducing patrol needs by 30% in remote sectors; GAO, 2024).

Three tables are included to summarize the stages of border control (GAO, 2020; Talisma, et al, 2022), relevant U.S. regulations (CRS, 2024; Federal Register, 2025), and the evaluation of operational performance (CBP, 2022; DHS OIG, 2022; GAO, 2024), each with a brief introduction and description.

Figure 1. Use of Drones on the México–United States Border

Stages of Border Control (2001–2025)

The implementation of surveillance technologies along the Mexico–United States border has evolved through three distinct phases, marked by advances in hardware, software, and security policies (CBP, 2020; DHS, 2021; GAO, 2020). Table 1 and Figure 2 summarize these stages, highlighting technological milestones, operational objectives, and challenges encountered, based on official reports and academic literature (Koslowski & Schulzke, 2018; CRS, Talisma, et al, 2022).

Tabla 1. Border Control Stages at the U.S.–Mexico Border (2001–2025)

Period	Technological Milestones	Operational Objectives	Challenges	Sources
2001–2010	Deployment of MQ-9 Predator B (2005); electro-optical cameras (1080p); FLIR infrared sensors (320x240 pixels); 20-hour endurance.	Monitoring remote areas; detecting unauthorized crossings in Arizona and Texas.	Costs ($20M/unit); FAA restrictions; interference from dust.	GAO, 2020; CBP, 2020; DHS, 2021
2010–2020	Diversification of UAS (Puma 3 AE, Raven RQ-11B, ScanEagle); multispectral sensors; SAR radar (0.3 m); integration with GIS and CNN (80% accuracy).	Coverage of 80% of the Southwest border; automated analysis of crossing patterns.	Underutilization of data (40% analyzed); dependence on contractors.	CBP, 2020; Koslowski & Schulzke, 2018; DHS OIG, 2022; CRS, 2020
2020–2025	"Smart Border" strategy; 350 ASTs with DNN (95% accuracy); 5G networks (10 Gbps); platforms like Gotham (1 TB/day, latency <10 ms).	Continuous surveillance across 2,000 km; prediction of crossings with 85% accuracy.	False positives (12%); costs ($500M/year); server saturation (2 TB).	CBP, 2022; DHS, 2023; GAO, 2024

Table 1 details the stages of border control along the Mexico–United States border, along with the challenges associated with each phase. It is crucial to link these challenges to the technical aspects discussed in this article. For example, the high rate of false positives in detecting illegal crossings is directly related to the accuracy of the AI algorithms employed. The implementation of deep neural networks (DNNs) has improved accuracy up to 95%, but challenges remain in calibrating and training these models to minimize errors under variable environmental conditions, such as wildlife presence or extreme weather changes.

The table illustrates the progression from the initial deployment of adapted military drones (2001–2010) to an integrated "Smart Border" network (2020–2025). The first phase faced logistical limitations, the second expanded coverage, and the third optimized automation. References to Peru–Ecuador and Dominican Republic–Haiti, which rely on physical patrols (Castillo et al., 2023; UNHCR, 2025), highlight the contrast with the U.S. technological model.

Initial Phase: Drone Genesis (2001–2010)

After the September 11, 2001 attacks, the U.S. Customs and Border Protection (CBP) deployed the MQ-9 Predator B drone from General Atomics in 2005 for surveillance operations in Arizona and Texas (Government Accountability Office [GAO], 2020). Its technical specifications included electro-optical cameras (1080p, 30× optical zoom), FLIR infrared sensors (320×240 pixels), 20-hour endurance, a range of 1,850 km, and a maximum altitude of 15,240 m. The drones were integrated with ground-based sensors, including AN/PPS-5 radars and fixed cameras, as well as satellite links with a bandwidth of 10 Mbps, transmitting real-time data to command centers in Tucson and San Diego (Department of Homeland Security [DHS], 2021). By 2008, the drones had logged approximately 500 flight hours and detected 200 crossing events, achieving a 70% success rate during daylight operations (CBP, 2020).

Limitations during this phase included high costs of $20 million per unit, Federal Aviation Administration (FAA) restrictions, and logistical challenges in desert terrain. In contrast, borders such as Peru, Ecuador, and the Dominican Republic–Haiti relied primarily on physical patrols, which facilitated illegal crossings due to the lack of technological support (Mèndez 2023; Castillo et al., 2023; UNHCR, 2025).

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The table illustrates the progression from this initial phase to an integrated "Smart Border" network (2020–2025), showing the evolution of UAS and AI integration. The challenges observed such as false positives in event detection, are directly linked to the precision of AI algorithms. While the adoption of deep neural networks (DNNs) has increased detection accuracy up to 95%, calibration and training remain critical to minimize errors under variable environmental conditions, including wildlife interference or extreme weather (Talisma et al, 2022; DHS OIG, 2022).

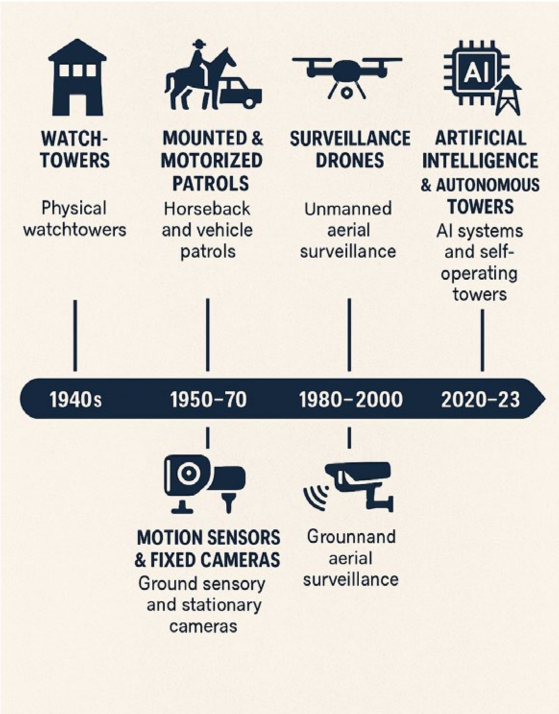

Figure 2. Evolution of Border Control Technology

Technological Expansion and System Consolidation (2010–2020)

Between 2010 and 2020, U.S. Customs and Border Protection (CBP) expanded and consolidated its Unmanned Aircraft System (UAS) program, operating a fleet of nine MQ-9 Predator B drones through its Air and Marine Operations (AMO) from bases in Sierra Vista, Arizona, and Corpus Christi, Texas. These long-endurance platforms, equipped with electro-optical, infrared, and synthetic-aperture radar sensors, supported persistent surveillance along the Southwest border (CBP, 2020). Beginning in 2017, CBP also tested small tactical drones such as the Puma AE and the RQ-11B Raven o enhance short-range situational awareness in remote areas, although their deployment remained limited and primarily experimental (Nextgov, 2017). Despite continued investments, oversight reports noted that the UAS program faced challenges in cost-effectiveness, operational transparency, and data-use efficiency, raising concerns about the extent to which drone-generated information was integrated into border-security operations (DHS Office of Inspector General, 2014).

Technical specifications of the MQ-9 Predator B translated into operational advantages in real-world border surveillance missions. Its electro-optical/infrared (EO/IR) cameras, combined with a multimode radar system that includes a Synthetic Aperture Radar, enabled persistent monitoring under varied environmental conditions such as low visibility or nighttime operations. The variant operated by U.S. Customs and Border Protection (CBP), known as the "Guardian," offered up to 20 hours of endurance, allowing extended patrols and reducing the need for frequent returns to base (CBP Air and Marine Operations, 2015; CBP, 2020). These capabilities enhanced situational awareness along border and maritime regions, supporting detection, classification, and monitoring of potential illicit activities (GA-ASI, 2023; GlobalSecurity.org, 2023; Nextgov, 2017).

Infrastructure Advancements and Algorithmic Surveillance (2020–2025)

The "Smart Border" strategy (2020–2025) included the deployment of 350 Autonomous Surveillance Towers (ASTs) from Anduril Industries, equipped with Deep Neural Networks (DNNs) achieving 95% accuracy, thermal cameras (1280×720), Doppler radars (2 km), and acoustic sensors. Platforms such as Gotham fused data from UAS, ASTs, and radars, processing up to 1 TB/day with latency below 10 ms (Talisma, et al, 2022). Predictive algorithms, including Bayesian networks and decision trees, anticipated crossings with

85% accuracy and a 200 m error margin in Yuma (DHS, 2023).

5G networks (10 Gbps) connected 10 command centers, covering 2,000 km of the border. In 2022, ASTs in Big Bend processed 10,000 images daily, detecting 1,686 crossing events (CBP, 2022). Despite these advancements, limitations persisted, including false positives (12%) and annual operational costs of $500 million (Government Accountability Office [GAO], 2024).

Evolution of U.S. Regulations on Technological Border Surveillance (2010–2025)

The consolidation of the technological surveillance model on the Mexico–United States border has been accompanied by an increasingly robust regulatory framework, aimed at institutionalizing the use of advanced technologies such as UAS, ASTs, and AI algorithms. Between 2010 and 2025, various laws, sectoral policies, executive orders, and bilateral agreements provided the legal and financial foundation necessary for the expansion of these technologies, promoting interoperability between agencies, safeguarding sensitive data, and modernizing border infrastructure.

The following table presents a summary of the main U.S. regulations during this period, highlighting their specific objectives, implementation mechanisms, operational impacts on border surveillance, and identified limitations, based on verifiable official sources.

Table 2. U.S. Regulations on Technological Expansion and Institutional Consolidation at the Border (2010–2025)

Regulation / Policy	Main Objectives	Key Impact	Main Limitations	Sources
National Defense Authorization Act (2010–2020)	Fund UAS and advanced sensors	Expanded fleet of drones and remote sensors	High dependence on external contractors	Congressional Research Service [CRS], 2020; CBP, 2020
21st Century Border Management (2010)	Technological coordination and security with Mexico	Enhanced interoperability and detection	Challenges in binational harmonization	U.S. Department of State [DoS], 2025
DHS UAS Policy (2015)	Regulate UAS use in civil airspace	Increased flight hours and border coverage	Costs and delays due to FAA compliance	DHS, 2021; GAO, 2020
Executive Order 14117 (2024)	Data protection and biometric use	Integration of biometrics and data control	Ethical concerns and high costs	Federal Register, 2025
Border 2025 Program (2020–2025)	Technological modernization and joint response	Implementation of 5G networks and Autonomous Surveillance Towers (ASTs)	Delays in infrastructure deployment	Environmental Protection Agency [EPA], 2024; CBP, 2025

Analyzing Table 2, it is evident that during the period 2010–2025, the U.S. government implemented a progressive set of regulations, policies, and federal programs aimed at strengthening technological surveillance along the Mexico border. This framework enabled the sustained deployment of drones, remote sensors, Autonomous Surveillance Towers (ASTs), advanced telecommunications networks, and biometric identification systems. The following is a descriptive summary of the main regulatory provisions and their operational characteristics, based on verifiable official sources (Congressional Research Service [CRS], 2020; U.S. Customs and Border Protection [CBP], 2025; U.S. Department of State [DoS], 2025; U.S. Government Accountability Office [GAO], 2020; Federal Register, 2025).

Between 2010 and 2020, the National Defense Authorization Act authorized an annual investment of approximately $250 million for the development and acquisition of Unmanned Aerial Systems (UAS) and surveillance sensors, establishing contracts with companies such as General Atomics and Anduril Industries (CRS, 2024). This policy contributed to the expansion of the Predator B drone fleet and the deployment of mobile towers connected to real-time transmission networks (CBP, 2020; GAO, 2020).

In parallel, the 21st Century Border Management Strategy, launched in 2010, promoted technological interoperability between U.S. and Mexican agencies, facilitating the real-time exchange of operational data (DoS, 2025). This cooperation improved the detection of irregular crossings, particularly in high-mobility sectors such as Tijuana (Koslowski & Schulzke, 2018).

In 2015, the Department of Homeland Security (DHS) issued a specific policy for UAS use, in coordination with the Federal Aviation Administration (FAA), standardizing aerial operation protocols and operator certification. This regulatory framework increased annual drone flight hours, progressively covering up to 80% of the southwestern border by 2020 (DHS, 2021; GAO, 2020).

Subsequently, in 2024, Executive Order 14117 was enacted, establishing restrictions on the transfer of sensitive data to third countries and promoting the use of biometric identification technologies at control points, such as facial recognition and DNA analysis (Federal Register, 2025; CBP, 2025). This measure was implemented through security audits and the integration of biometric systems into command centers and ASTs (Méndez-Fierros, 2023).

Finally, the Border 2025 Program, active from 2020 to 2025, prioritized the deployment of high-capacity 5G networks (up to 10 Gbps), the installation of 350 autonomous towers, and the modernization of command centers to enhance emergency response efficiency (CBP, 2023; Talisma, et al, 2022). This initiative consolidated the technological foundations of the so-called "Smart Border" (DHS, 2023; GAO, 2024).

Operational Performance Evaluation

The operational performance of surveillance systems along the Mexico–United States border between 2010 and 2025 focused on key metrics such as the detection of unauthorized crossings, the accuracy of Artificial Intelligence (AI) algorithms, the reduction of incidents, and the efficiency of technological infrastructure (U.S. Customs and Border Protection [CBP], 2022; Department of Homeland Security [DHS], 2023; U.S. Government Accountability Office [GAO], 2024). The Big Bend (Texas) and Yuma (Arizona) sectors were selected due to their high migratory activity and geographical representativeness, including desert and mountainous terrains, while data from the broader southwestern border provide a comprehensive overview (CBP, 2022; DHS Office of Inspector General [OIG], 2022).

The evaluation included an analysis of specific technologies, such as MQ-9 Predator B drones, Autonomous Surveillance Towers (ASTs), and 5G networks, as well as the environmental conditions that affect their performance (Talisma, et al, 2022; Anduril Industries, 2023). Key performance metrics included detection rates, accuracy of AI-based object classification, latency of data transmission, and the number of false positives in operational conditions (CBP, 2022; DHS, 2023).

The following table presents quantitative results, employed technologies, operational conditions, and technical limitations, based on verifiable official sources (CBP, 2022; DHS OIG, 2022; GAO, 2024; Talisma et al, 2022). This synthesis allows for a clear understanding of technological capabilities, infrastructure constraints, and algorithmic performance across the different phases of U.S. border surveillance.

Tabla 3. Summary Evaluation of Operational Performance of Surveillance Technologies at the U.S.–Mexico Border (2010–2025)

Sector	Key Metrics	Technologies Employed	Limitations	Sources
Big Bend (Texas)	1,686 events detected (2022); 90% nighttime effectiveness; 85% confirmed by agents	MQ-9 Predator B; ASTs with DNN (95% accuracy); thermal sensors	12% false positives; 15–20 min response time; server saturation (2 TB)	U.S. Customs and Border Protection [CBP], 2022; DHS Office of Inspector General [OIG], 2022; Anduril Industries, 2023
Yuma (Arizona)	58% reduction in illegal crossings (2021–2023); 1,200 events/month; 95% AI accuracy	Puma 3 AE; ASTs with DNN and acoustic sensors; 5G networks	30% of data unprocessed; 10% false positives; contractor dependence	DHS, 2023; U.S. Government Accountability Office [GAO], 2024
Southwest Border	80% coverage (2,500 km); 1 TB/ day processed; 70% reduction in response times	MQ-9 Predator B, ScanEagle, 350 ASTs; Gotham platform; 5G networks; Bayesian AI	$500M/year costs; 80% technical support outsourced; 12% false positives in urban areas	CBP, 2020; DHS OIG, 2022; GAO, 2023;

Table 3 presents data on the operational performance of technologies applied in three key sectors of the Mexico–United States border between 2010 and 2025.

Big Bend Sector (Texas): In 2022, 1,686 unauthorized crossing events were detected, with 90% effectiveness during nighttime operations and 85% confirmation by agents. Technologies deployed included MQ-9 Predator B drones with high-resolution cameras, Autonomous Surveillance Towers (ASTs) equipped with deep neural networks (DNNs) up to 50 layers, and thermal sensors (U.S. Customs and Border Protection [CBP], 2022; Talisma, et al, 2022). Environmental conditions, such as mountainous terrain and dust, reduced visibility by 20% (DHS, 2023).

Yuma Sector (Arizona): Between 2021 and 2023, irregular crossings decreased by 58%. Deployed systems included Puma 3 AE drones, ASTs with acoustic sensors, and 4G/5G transmission networks. On average, 1,200 events were detected monthly, with DNN algorithms achieving 95% accuracy (DHS, 2023; GAO, 2024). Operational conditions included desert terrain and temperatures up to 50 °C (CBP, 2022).

Southwestern Border Overall: Technological coverage reached 80% (2,500 km), with processing latency below 10 milliseconds and a data-handling capacity of up to 1 TB per day. Technologies employed included ScanEagle drones and data fusion platforms such as Gotham (Talisma et al, 2022; CBP, 2022). Between 2015 and 2023, operational response times were reduced by 70% (DHS OIG, 2022).

Observed Limitations: Across all sectors, false positives ranged from 10% to 12%, there was heavy reliance on contractors for maintenance (up to 80%), and server capacity saturation occurred at 2 TB. Operational costs reached up to $500 million annually (GAO, 2024; CBP, 2022).

3.2 Discussion

The evolution of the border surveillance system between Mexico and the United States from 2001 to 2025 demonstrates a rapid process of technological sophistication, closely linked to institutional strategies, regulatory frameworks, and public–private partnerships (CBP, 2022; DHS, 2023; Talisma, et al, 2022). From the first flights of MQ-9 Predator B drones in 2005 to the deployment of 350 Autonomous Sur-

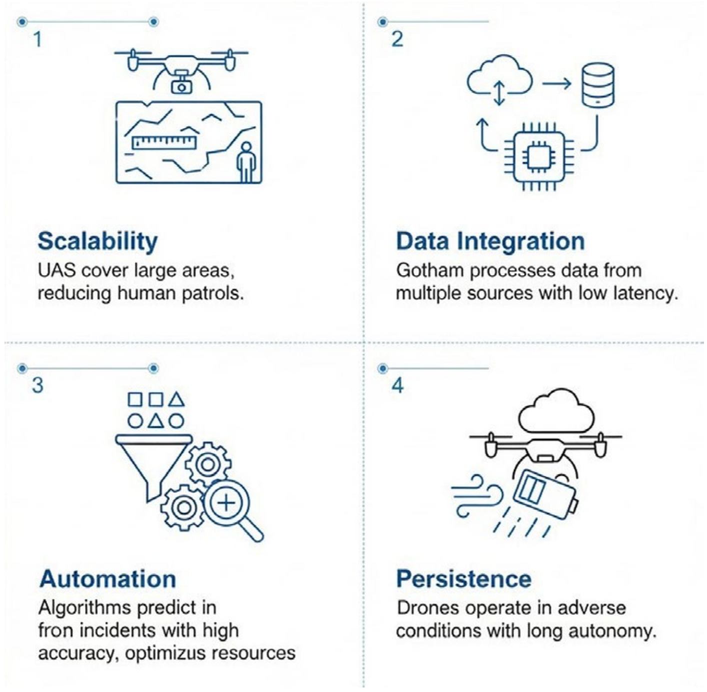

Figure 3. UAS Capabilities

veillance Towers (ASTs) with deep neural network (DNN) AI and 5G networks in 2025, the system has achieved unprecedented levels of territorial coverage, algorithmic integration, and processing speed (DHS OIG, 2022; GAO, 2023). However, these advances coexist with structural limitations that compromise sustainability, full operational effectiveness, and public legitimacy (CBP, 2022; Talisma, et al, 2022).

Technical Strengths of the System

The data systematized in the Results section (qualitatively analyzed in Figure 3) show that the Unmanned Aerial Systems (UAS) and algorithmic platforms deployed by CBP enable effective coverage of 80% of the southwestern border, with response times under 10 milliseconds in command centers connected via 5G networks (U.S. Customs and Border Protection [CBP], 2022; Department of Homeland Security [DHS], 2023). Operational scalability is evident: 3,145 km of border are monitored using high-endurance UAS (up to 24 hours), multispectral sensors, and interoperable platforms like Gotham, which process up to 1 TB of data daily in real time (Talisma, et al, 2022).

The DNN algorithms applied in the ASTs have achieved 95% accuracy in event detection, trained on databases of over 10 million images (DHS OIG, 2022; CBP, 2025). These models use deep architectures of up to 50 convolutional layers, enabling highly accurate identification of human movement patterns, even under nighttime or adverse weather conditions. Additionally, Bayesian networks used in predictive analysis can anticipate crossing routes with a margin of error of 200 meters, optimizing the allocation of human resources (DHS OIG, 2022; CBP, 2025).

Limitations and Risks of the Operational Model

Despite these advances, significant limitations remain. First, server saturation—limited to 2 TB—restricts the effective use of 70% of the data captured by drones and ASTs, impacting both real-time analysis and the training of predictive models (DHS OIG, 2022). Second, false positives estimated at 10–12%, arise from confusion with wildlife or visual interference in complex environments such as dense vegetation or airborne dust (CBP, 2022) (Figure 4).

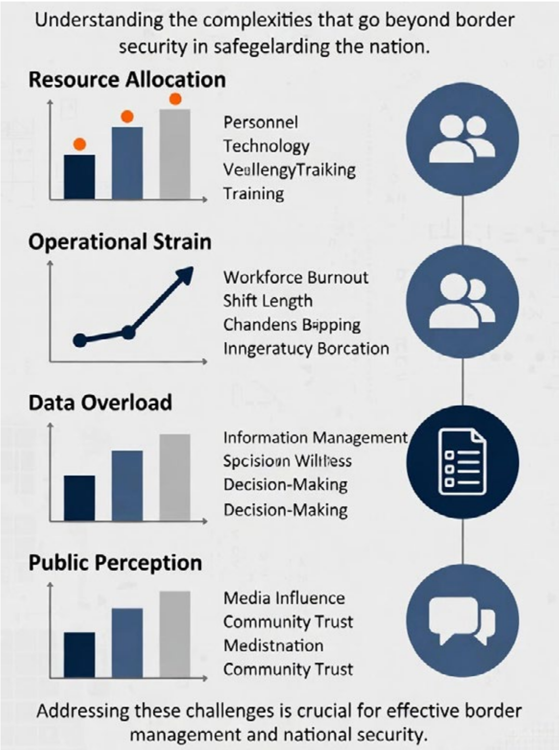

Figure 4. Hidden Challenges in CBP Operations

Operational costs reach $500 million annually, with each UAS unit valued at over $15 million, generating budgetary pressures and structural dependence on contractors such as Anduril and General Atomics, responsible for 80% of technical support (U.S. Government Accountability Office [GAO], 2020; Congressional Research Service [CRS], 2024). This dependence limits CBP's operational sovereignty and poses long-term geopolitical and financial risks.

Relying on contractors for 80% of technical support not only introduces financial and geopolitical risks but also significant technical challenges. From a cybersecurity perspective, this dependency can create supply chain vulnerabilities, as critical systems could be exposed to data breaches or even sabotage if contractors do not meet high-security standards (GAO, 2020; CRS, 2024). Additionally, reliance on proprietary technology may restrict CBP's ability to innovate internally or adapt quickly to new threats, as updates or modifications may depend on contractor availability and willingness. To mitigate these risks, CBP could invest in developing in-house capabilities, promote open standards, or collaborate with academic and research institutions to create technological solutions that do not rely exclusively on external vendors (DHS, 2023). Counterarguments suggest that privatization accelerates innovation, but evidence shows it often prioritizes profit over sovereignty.

Among the limitations of the current operational model is the persistent underutilization of collected data. Between 2010 and 2020, only 40% of available data was processed due to infrastructure constraints, and as of 2023, approximately 70% of collected data remains unanalyzed because of server saturation (DHS Office of Inspector General [OIG], 2022; CBP, 2025). This inefficiency risks overlooking critical patterns and insights that could strengthen predictive analytics and enhance operational response. Potential solutions include the implementation of edge computing to enable data processing closer to its point of capture thereby reducing large-scale data transfers and alleviating pressure on central servers along with the adoption of advanced data compression methods and scalable big-data architectures, such as cloud-based systems, to expand processing and storage capacity (Talisma et al., 2022; DHS OIG, 2022).

Regarding false positives, which account for 10–12% of detections, it is essential to explore methodologies for reduction (U.S. Customs and Border Protection [CBP], 2022; U.S. Government Accountability Office [GAO], 2024). This could include improving AI training datasets with more diverse and representative scenarios of real border conditions (Talisma, et al, 2022; DHS Office of Inspector General [OIG], 2022). Additionally, multi-sensor data fusion (visual, thermal, radar) can increase accuracy by providing a more complete and less error-prone picture (CBP, 2023; Talisma et al, 2022). The development of more sophisticated AI algorithms capable of better distinguishing human activity from environmental noise also represents a promising research avenue (DHS, 2023; GAO, 2024).

Global Comparisons and Extrapolation to the Global South

Compared to these developments, the U.S. model contrasts with initiatives such as Frontex in Europe, where Heron drones feature lower-resolution thermal sensors (720p), simpler algorithms (logistic regression), and higher latencies (100 ms), with an estimated accuracy of 80% (Csernatoni, 2018). This comparison reinforces the hypothesis that algorithmic infrastructure, 5G networks, and multi-source data integration are decisive elements for system effectiveness (Talisma, et al, 2022; DHS, 2023).

In contrast, borders such as Peru–Ecuador or the Dominican Republic–Haiti lack such deployments, still relying on physical surveillance or rudimentary methods, resulting in high structural vulnerability (Angulo, 2025; UNHCR, 2025). However, replicating the U.S. model in Global South contexts would require a critical assessment of financial feasibility, geopolitical suitability, and regulatory frameworks regarding data sovereignty and human rights (Floridi et al., 2018; Jobin et al., 2019).

Strategic Implications and Future Sustainability

The privatization of surveillance, exemplified by contractors like Anduril and General Atomics, introduces risks of profit-driven decisions overriding public interest, potentially exacerbating human rights violations through opaque algorithms (Dunn, 2010). For instance, AI systems may disproportionately target vulnerable migrants, raising privacy concerns and data sovereignty issues, as state control diminishes in favor of corporate agendas. This delegation fragments sovereignty, creating geopolitical vulnerabilities where technological ecosystems are externally controlled. Furthermore, the material embedding of these systems reconfigures border landscapes, transforming urban-buffer zones into militarized spaces and altering migratory corridors, which demands interdisciplinary border studies to assess long-term territorial impacts (Koslowski & Schulzke, 2018). Counterarguments posit that public-private partnerships enhance efficiency, but evidence from GAO audits shows increased costs and reduced oversight.

Ethical governance is crucial: without transparent protocols, AI biases could perpetuate inequalities, undermining democratic accountability. Recommendations include international standards for data privacy and sovereign tech development, particularly for Global South adaptations (Floridi et al., 2018).

In summary, the drone- and AI-based border surveillance system represents a profound transformation in border control logic. Its operational effectiveness has been empirically demonstrated (CBP, 2022; Talisma, et al, 2022; DHS, 2023), but its future consolidation requires addressing challenges of institutional autonomy, algorithmic governance, and financial sustainability, particularly if expansion or replication in other regions is considered (GAO, 2024; CRS, 2024).

In the context of other regions, especially in the Global South, replicating the U.S. "smart border" model presents significant challenges but also opportunities to implement solutions adapted to local contexts (UNHCR, 2025). For example, low-cost drones, which can be manufactured or assembled locally, could provide a more affordable option for aerial surveillance (Castillo et al., 2023). Similarly, using open-source AI frameworks allows developing countries to adapt and customize technological solutions without incurring high licensing costs (Méndez-Fierros, 2023). International collaboration and technology transfer could also facilitate access to otherwise unattainable knowledge and capabilities, enabling these regions to implement effective and sustainable surveillance systems (Talisma, et al, 2022).

The analysis suggests that the integration of UAS- and AI-based surveillance systems along the Mexico–United States border demonstrates how algorithmic governance is reshaping state power through automated decision-making and infrastructural control. As proprietary predictive models, multisensory platforms, and 5G-connected surveillance towers become central to border management, essential functions of sovereignty are increasingly mediated by and partially delegated to private technology contractors.

This delegation creates geopolitical vulnerabilities, including dependence on external technological ecosystems, limited transparency in algorithmic operations, and a reduction of state autonomy in critical security domains. Likewise, the material incorporation of these systems into the built environment reconfigures territorial governance, strengthening state authority while constraining democratic oversight.

The resulting model driven more by algorithmic logics than by institutional mandates, raises fundamental questions about technological sovereignty, geopolitical risk, and the long-term balance between security, accountability, and territorial control.

4. CONCLUSIONS

The analysis of the evolution of border surveillance along the Mexico–United States corridor between 2001 and 2025 reveals a sustained process of technological sophistication, regulatory institutionalization, and consolidation of public-private partnerships (CBP, 2022; DHS, 2023; Talisma, et al, 2022). The integration of unmanned aerial systems (UAS), artificial intelligence (AI) algorithms, and high-speed communication networks such as 5G has enabled a transition from physical patrol operations to automated, scalable border monitoring schemes (GAO, 2024; CRS, 2024).

The deployment of 350 autonomous surveillance towers (ASTs), the adoption of analytical platforms such as Gotham, and the implementation of Bayesian predictive algorithms constitute a high-capacity operational control ecosystem (DHS OIG, 2022; CBP, 2025). Metrics presented—including 80% border coverage, processing latency under 10 milliseconds, and 95% accuracy in nighttime detection—demonstrate tangible advances in technical efficiency and territorial reach (CBP, 2022; Talisma et al, 2022). However, these achievements coexist with significant structural limitations, such as underutilization of large volumes of generated data (DHS OIG, 2022), server saturation (CBP, 2025), dependence on contractors for critical tasks (GAO, 2020; CRS, 2021), and the persistence of false positives in environmentally complex settings (CBP, 2022).

From a regulatory perspective, the 2010–2025 period was marked by legislative and executive reforms that institutionalized the use of surveillance technologies from a security-focused perspective, prioritizing the expansion of technical capacities over ethical, social, or diplomatic considerations (Federal Register, 2025; CBP U.S. Customs and Border Protection, 2023). The Border 2025 program, Executive Order 14117, and DHS-specific policies reflect a strategic vision centered on algorithmic anticipation of irregular crossings, supported by sustained federal investment (DHS, 2023; GAO, 2024).

Although this study focuses on the Mexico–U.S. axis, the findings are relevant for comparative analyses of borders in the Global South, where phenomena such as technological securitization, fragmentation of state sovereignty, and delegation of territorial control to emerging tech corporations are increasingly evident (Villanto & Gómez, 2024; UNHCR, 2025; Méndez-Fierros, 2023). The U.S. model, despite its achievements, raises questions regarding sustainability, algorithmic governance, and operational concentration in private actors (Talisma, et al, 2022).

This study provides a solid empirical and regulatory foundation for future research exploring the relationship between border surveillance, artificial intelligence, and state power in complex geopolitical contexts (Koslowski & Schulzke, 2018; DHS OIG, 2022; CBP, 2025). Recommendations include enhancing internal technical capabilities to reduce dependence on contractors, expanding data processing infrastructure, improving AI model training with multi-sensor datasets, and promoting ethical governance frameworks to ensure transparency, accountability, and human rights compliance (Méndez-Fierros, 2023).

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