



TECH4TRACING

# From Data to Detection

## AI-enhanced Weapons Detection in X-ray and CT Systems



### Key findings

- APIDS are becoming commercially available and are now being deployed throughout the EU. Some systems are machine-agnostic and capable of being retrofitted onto existing scanner infrastructure. Their operational deployment at several airports suggests a high technology readiness level (TRL 8–9), but benchmark (testing) evaluation datasets will need to keep up with the actual evolving firearms trafficking threat.
- First-generation APIDS appear to be trained primarily on annotated data sourced from their own systems. A barrier to the advancement and widespread reliable deployment of AI-enhanced systems is the lack of large-scale, high-quality, standardized datasets of X-ray images for training and testing. This limitation lowers detection robustness and generalization across different operational environments (Vukadinovic and Anderson, 2022).
- The gradual integration of AI shifts the role of the human operator from active search to prediction verification/confirmation. The effectiveness of this human-machine team is paramount and requires careful consideration of human factors, training, and trust in automation to avoid the ‘cry wolf’ effect (Vukadinovic and Anderson, 2022).
- EU-supported initiatives such as CEASEFIRE, AIDEDex, and Project Hermes have attempted to tackle key aspects of the problem in various ways, from developing integrated detection platforms to creating essential reference image libraries. Many of these solutions are positioned at a mid-to-high TRL (5–7), but do not appear to be market ready.

### Introduction

In law enforcement’s fight against the evolving threat of weapons and explosives trafficking, there are high expectations for artificial intelligence (AI) as a critical enabling technology, offering the potential to significantly augment threat detection and enhance the efforts of police and custom agencies to disrupt such trafficking. So far, however, AI’s effectiveness in detecting, identifying, and helping law enforcement agencies (LEAs) document and interdict illicit weapons has not been clearly described or understood. In part, this is because the technology is changing so rapidly, but also because of a lack of transparency by technology providers and a culture of persistent overpromising of what AI can achieve.

In line with Tech 4 Tracing’s (T4T) mission to help LEA beneficiaries understand what AI can and cannot achieve in the area of illicit weapons and explosives proliferation controls, this Policy Brief provides a state-of-play assessment of the application of AI, with a primary focus on its use in the automated prohibited items detection systems (APIDS) used by security services in the aviation and fast-parcel-screening domains. In particular, the assessment looks at computer vision (also sometimes called ‘AI computer vision’) in the automated detection of firearms, their parts and components, ammunition, and explosives within the X-ray spectrum. Baggage and parcel scanning are critical chokepoints for interdiction, particularly in the high-volume environments of postal hubs and border crossings. Dark Web monitoring, biometrics, and explosive forensics are other areas of innovation that stand to benefit from AI vision but lie outside the scope of this Policy Brief.

This initial assessment is intended primarily for the benefit of European Union (EU)-supported LEAs and their partners inside and outside the EU. Its relevance cuts across EU and global counter-proliferation, arms control, organized crime and counter-terrorism initiatives, policies, and commitments. Within the EU, the assessment is intended to help inform efforts to implement the 2025 EU Serious and Organised Crime Threat Assessment (SOCTA), which reflects the heightened priority of addressing illicit weapons and explosives trafficking. As such, it consolidates pre-existing information and data that were not widely circulated outside academic publications and has been supplemented by key informant interviews with industry and law enforcement representatives, and by information gathered from other sources. The Policy Brief ends with a series of recommendations for advancing capabilities from their current state to more effective, implementation-ready solutions.

The assessment employed a mixed-methods approach that combined desk research, stakeholder engagement, and comparative technology analysis. Desk research involved a structured review of peer-reviewed publications, key EU policy documents such as the SOCTA and EU AI Act, and technical reports from the EU Joint Research Centre (JRC),<sup>1</sup> INTERPOL and UN Interregional Crime and Justice Research Institute,<sup>2</sup> and the UN Office on Drugs and Crime (UNODC),<sup>3</sup> among

others. Vendor white papers and industry announcements were also reviewed to capture claims of commercial readiness. Discussions were held with international organizations, EU-level law enforcement bodies, and technical experts from ongoing research initiatives. These exchanges provided crucial operational perspectives and research insights and helped to validate emerging findings. Industry outreach involved engagement with commercial providers of APIDS solutions to gather technical details, deployment experiences, and product roadmaps. This information was then compared against available independent evaluations, although proprietary sensitivities limited the level of transparency in many cases. Limitations to the study included barriers to obtaining standardized performance datasets, access to live operational environments, and the validation of commercial vendors' technology readiness level (TRL) claims. Attempts to secure onsite observations and access to live, in-field demonstrations of AI-enabled detection systems, especially those offered by commercial actors, were also largely unsuccessful. As a result, parts of the analysis rely on reported information and expert opinion rather than fully independent testing data.

## The evolving threat and imperative for innovation

Law enforcement's ability to intercept illicit weapons in transit is becoming more difficult as several trends converge. The exponential growth of e-commerce has turned the global postal and express courier system into a primary vector for illicit weapons and explosives trafficking. Criminals exploit the high volume and speed of this network to ship disassembled firearms, parts and components, ammunition, and improvised explosive device (IED) precursors in small, inconspicuous packages. UNODC notes that "enhanced border control and risk profiling capacities are required to prevent and intercept illicit movement of firearms ... arriving through ... parcel and postal services deliveries" (UNODC, 2020, p. 86).

This presents an immense challenge for customs and police. The sheer volume of material to be inspected makes comprehensive physical inspection impossible. Consequently, there is a heavy reliance on non-intrusive inspection technologies,

primarily X-ray scanners. The effectiveness of this screening is the critical line of defence. The EU-funded Operation Armstrong, a joint effort involving UNODC and the European Multidisciplinary Platform Against Criminal Threats (EMPACT) Firearms, specifically targeted this weapons- and explosives-trafficking modus operandi in Latin America, revealing the scale of the issue and the need for enhanced detection capabilities at sorting hubs (UNODC, 2024).

Another significant emerging threat is the proliferation of privately manufactured firearms (PMFs), including 3D-printed weapons and firearms assembled from unregulated or unevenly regulated kits. These weapons

### Box 1. Wider AI computer vision weapons control applications

The scope of this assessment is deliberately focused narrowly on APIDS technology for the detection and identification of weapons and explosives in fast-parcel and customs scanning. But AI computer vision is well suited to address other important challenges in the illicit weapons and explosives proliferation domain. Some of these applications are already mature, while others have not yet been prototyped.

- **Remote detection of unexploded ordnance:** Since the onset of the Russia-Ukraine war, especially, the aerial detection of surface and sub-surface unexploded ordnance in post-conflict areas has innovated rapidly. Humanitarian actors and national authorities now conduct 'remote sensing' in unmanned aerial vehicles equipped with sensors using a range of wavelengths and spectra, including visual, thermal, magnetic, and ground-penetrating radar, among others.
- **Explosives residue and packaging identification:** In the Netherlands, which is highly affected by the criminal use of commercial fireworks in improvised explosives, law enforcement teams have piloted technology that can analyse and categorize the remnants of explosives' packaging using AI and machine learning.<sup>4</sup>
- **'Facial recognition' for ammunition:** T4T has demonstrated the feasibility of object detection and classification based on the standard markings applied to small calibre ammunition headstamps at manufacture (T4T, 2022). The incorporation of such deep-learning software into law enforcement systems could greatly enhance the quality and quantity of useable data for analysing illicit ammunition used in crimes. T4T is currently developing the first functional prototype of such a tool, linked to a small calibre ammunition reference table based on internationally recognized designations (nomenclature) provided by the Commission internationale permanente pour l'épreuve des armes à feu portatives and NATO.
- **Counterfeit firearms identification:** Counterfeit firearms production is becoming more sophisticated and industrialized, with factories producing high-quality replicas that even firearms experts have trouble distinguishing from real, legally made firearms.<sup>5</sup> Often the differences, such as the way serial numbers or company logos are applied to the weapons, are microscopic. With high-quality images of baseline (real) and counterfeit weapons, AI vision systems could be developed to distinguish legal from illegal weapons.

frequently lack serial numbers or legally mandated markings on essential components, making them harder to trace using traditional methods, although European and US researchers have demonstrated that AI and deep learning (see Figure 1) can ‘trace’ 3D-printed objects back to the specific printers that created them (Bimrose et al., 2025) (see Box 1).

The online component of the trafficking threat is particularly concerning: 3D-print files, blueprints, and manufacturing instructions are readily available and shared on both the open Internet and Dark Web. Further enhancing this risk, publicly available large language models (LLMs) such as ChatGPT are being tricked into divulging sources and methods for creating PMFs. Although many leading LLM interfaces have safeguards in place, tricking LLMs into sharing this information is still easily achieved through circuitous prompting. The CEASEFIRE project, a three-year project funded by Horizon Europe that ended in August 2025, had a specific work package dedicated to monitoring and analysing the online distribution of 3D-printed weapons blueprints, recognizing this as a critical node in the illicit manufacturing chain (Mademlis et al., 2024). These weapons pose a dual challenge: they are difficult to trace and their often-used polymer construction can make them harder to detect with conventional X-ray screening than traditional metallic firearms.

Taken together, these developments create a complex threat environment that cannot be met with reactive responses alone. LEAs will eventually need to shift towards proactive, technology-driven detection methods. AI is beginning to offer real possibilities in this respect by extending analytic capacity, handling data volumes far beyond human capabilities, and uncovering patterns that might otherwise remain undetected. But the state of play must be continually reviewed not only because technologies

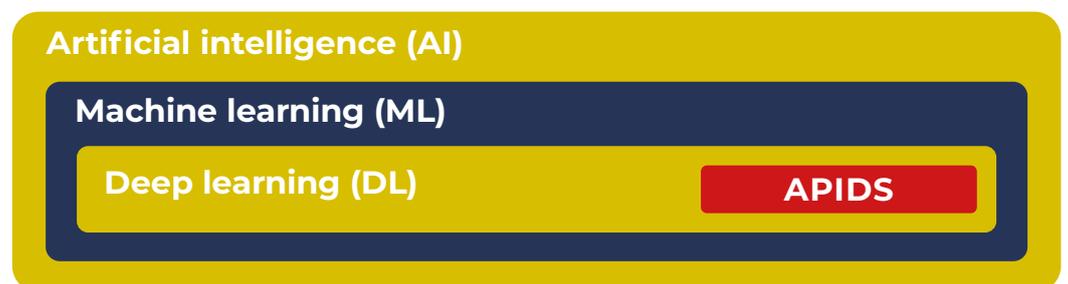
evolve quickly, but also because of the significant overpromise of the readiness levels of vendor solutions.

Within the EU, the SOCTA provides the strategic foundation for the multi-year Operational Action Plan for EMPACT (Europol, 2025). The elevation of illicit firearms and explosives to a key threat focus in the 2025 SOCTA underscores the political and operational priority of this issue. A clear understanding of the available and emerging AI technologies is therefore essential for shaping the next EU counter-trafficking and organized crime policy cycle, as well as operational actions organized and coordinated through the EMPACT platform.

## The role of AI in X-ray security screening

The core technological response to the threat of trafficked weapons in high-volume streams like fast-parcel post and baggage is the integration of AI object detection algorithms into X-ray and CT (computed tomography) screening systems.<sup>6</sup> This could represent a paradigm shift from reliance on human operators alone to a collaborative human-machine approach.

The application of AI in this domain is realized through so-called automated prohibited item detection systems (APIDS), also known as automated threat recognition systems. These are sophisticated software platforms that analyse image data from X-ray or CT scanners to automatically identify potential threats. When the algorithm detects an object of interest, it alerts the human operator, typically by overlaying a coloured bounding box on the human screener’s display, allowing for immediate secondary human inspection (CASRA, 2023). This augments the screener’s ability to detect threats, especially in clutter images and under conditions of physical and mental fatigue in a low-stimulus environment, when the likelihood of false-negative detections is increased.



**Figure 1. Relation of APIDS and deep learning to AI**  
(Source: CASRA, 2023)

APIDS are a specialized application of machine learning (ML), where systems learn to recognize patterns from data generated by it rather than being explicitly programmed for every possible variable, or trained on other forms of data like synthetic data created outside the detection platform. The vast majority of modern APIDS utilize deep learning (DL), an ML subset that employs deep artificial neural networks with many layers (see Figure 2).

DL models are particularly adept at AI computer vision tasks. They learn to identify objects by analysing millions of labelled images, progressively building up a hierarchical understanding of features ranging from simple edges and textures in the initial layers to complex object parts and entire objects in deeper layers (Vukadinovic and Anderson, 2022). The performance of these models is directly correlated with the quantity and quality of the data they are trained on, so data is the critical factor in their effectiveness.

## APIDS performance and limitations

While APIDS offer significant enhancements, their reliability and performance can vary. Understanding performance characteristics and limitations is thus crucial for the effective deployment of APIDS and points to where further improvements to effectiveness can be made.

**Performance metrics:** While vendors may report high detection rates (DRs) there is rarely clarity about how these are calculated, and against what benchmarks, as is discussed further below. The false alarm rate (FAR), or false positive rate, is also a critical metric, because a high FAR can disrupt operational flows and lead to operator fatigue. Current commercial systems typically report FARs below 5 per cent (CASRA, 2023), although these figures have not been independently verified.

**Image-based limitations:** The primary limitations of APIDS stem from the physics of X-ray imaging itself. The most significant challenge for both human operators and AI in the X-ray spectrum is *superposition*. When multiple objects are stacked on top of one another, their X-ray signatures overlap, increasing the risk of a threat item being obscured. Densely packed and complex baggage result in *cluttered images* in which

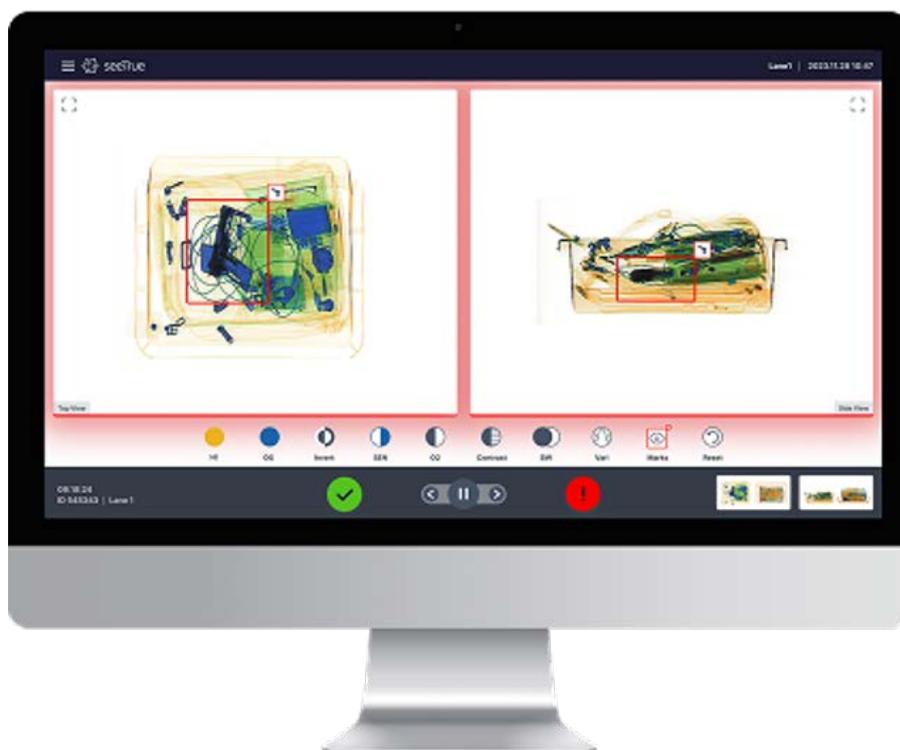
the identification of individual objects is made more difficult. Finally, a weapon viewed from an unusual angle (e.g. a handgun pointing directly at the X-ray source) can present a less recognizable profile. This problem of object *orientation* is more challenging in X-ray's 3D space compared to 2D conventional RGB (red, green, and blue light, also referred to as 'visual spectrum') imagery.

Multi-view and 3D CT scanners help mitigate these issues by providing additional perspectives, allowing the AI (and the human operator) to 'see around' occluding objects. However, even with advanced imaging, these challenges have not yet been resolved, and ongoing research and algorithm development are needed to address them.

Finally, not all commercial X-ray systems use the same wavelengths of the X-ray spectrum. Commercial competition considerations aside, the ecosystems of X-ray scanners employed by law enforcement, transport, and customs authorities are therefore not uniform, raising the difficulty of pooling training data or deploying detection algorithms from one proprietary system to another.

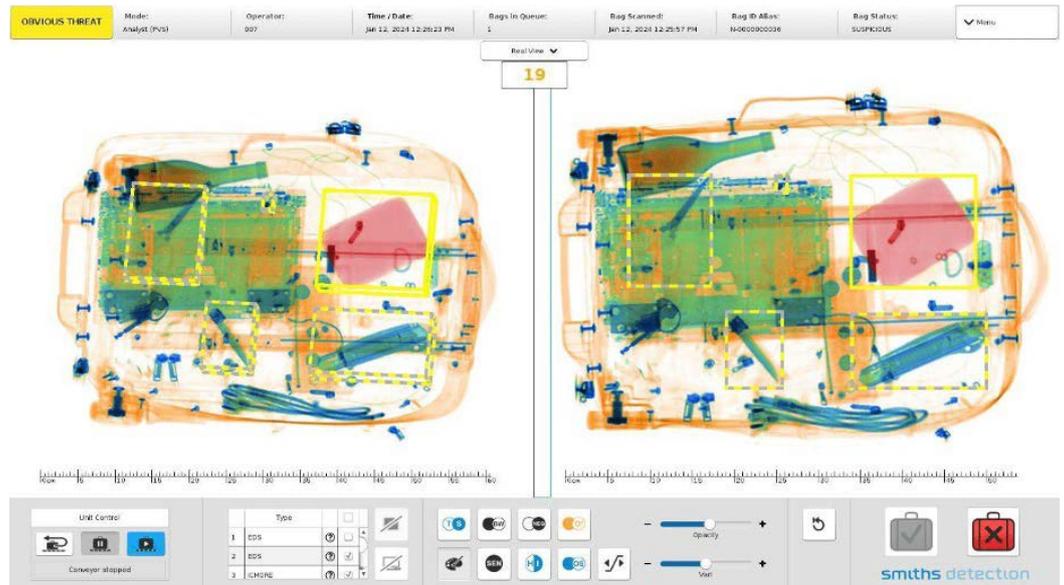
Figures 2 and 3 represent typical APIDS user interfaces for baggage scanning systems with indicative bounding boxes highlighting suspicious items.

**Figure 2. SeeTrue APIDS user interface**  
(Source: SeeTrue)



**Figure 3. ICMore system interface from Smiths Detection**

(Source: Smiths Detection)



## Assessing commercial APIDS

The market for AI-driven threat detection in X-ray screening has moved beyond the research phase and into commercial deployments. A growing ecosystem of commercial technology providers, ranging from established scanner manufacturers to specialized AI software companies, now offer APIDS solutions. Understanding this landscape is crucial for procurement and strategic planning.

The commercial field includes both original equipment manufacturers (OEMs), who integrate AI directly into their hardware, and third-party software developers creating machine-agnostic solutions. The landscape is also notable for diverse imaging technologies and business models, including strategic acquisitions by major defence and data analytics firms.

**Major integrated system providers:** Large, established companies like Smiths Detection, Leidos, Rapsican Systems, and NUCTECH represent the largest players in the market, and are all rolling out AI-assisted systems.

**Machine-agnostic AI software specialists:** A dynamic segment consists of companies focused purely on AI software. SeeTrue Screening and Pangiam stand out, with platforms undergoing advanced trials and deployments at major international airports. This software-centric model has significant commercial interest, as demonstrated by

Palantir Technologies' acquisition of Synapse Technology, a pioneer in this space. This move could signal a trend towards integrating checkpoint detection data into broader national security intelligence platforms.

**Diverse and complementary hardware:** The hardware market is not monolithic. VOTI Detection, which is now supported by Rapsican, offers a distinct approach with its 3D Perspective technology, which generates 3D-like images from a single X-ray source, representing an alternative to standard 2D imaging or full CT systems. In the people-screening domain, the AI-powered sensor approach of Evolv Technology is complemented by the high-resolution, ultra-low-dose X-ray body scanners from companies like Tek84, whose systems are designed to find concealed items both on and within the body. Technologies that address the inherent limitations of X-ray are also emerging. RaySecur provides a mail and parcel scanner that uses mmWave technology, which appears to be effective at detecting non-metallic threats like powders and liquids that are key IED components, though it requires a human operator to manipulate each parcel separately (no continuous belt conveyance).

This varied ecosystem of integrated OEMs, agile software firms, and innovators in alternative hardware illustrates a mature and competitive market actively developing solutions to counter evolving threats (see Table 1).

**Table 1. Readiness of commercial APIDS**

**1. Commercial hardware-software (integrated solutions)**

Vendor	Key AI product(s)	Description and capabilities	Indicative TRL & source*
<b>Astrophysics</b>	XIS Series with integrated AI software	An OEM of X-ray scanners that integrates its proprietary AI software for the automated detection of guns, knives, and other threats. The system is designed to stop the baggage/parcel conveyor belt and highlight threats to assist operator decision-making. The deep learning algorithms are engineered to improve over time.	TRL 9 (Astrophysics, n.d.; TSA qualification)
<b>Evolv Technology</b>	Evolv Express	An AI-powered system for people screening using advanced sensor technology (not X-ray) to detect weapons in high-throughput environments.	TRL 9 (adjacent) (Evolv Technology, n.d.; US DHS, n.d.)
<b>Halo X-ray Technologies</b>	Halo X-ray Scanner	Focuses on innovative X-ray diffraction hardware technology to identify materials and reduce false alarms.	TRL 7 (Halo X-ray Technologies, n.d.)
<b>IDSS (now SureScan)</b>	DETECT 1000	A CT-based checkpoint scanner with integrated AI for automated threat detection.	TRL 8 (TSA, 2025; SureScan, 2024)
<b>Leidos</b>	ClearScan; Pro:Vision with AI; ProSight	A portfolio of screening technologies, including CT and people scanners, which incorporate AI/ML for threat detection. Also integrates third-party AI systems, such as SeeTrue.	TRL 9 (Leidos, n.d.)
<b>LINEV Systems</b>	A-EYE; AI-powered mobile vehicle scanners	Software A-EYE is an AI system intended for the automated identification of firearms, firearm components, ammunition, grenades, knives, and brass knuckles. The detection algorithm is an embedded part of their baggage inspection systems.	TRL 8 for weapons; TRL 9 for contraband
<b>NUCTECH</b>	Kylin series CT scanners; WEKNOW AI platform	An extensive portfolio of CT and X-ray scanners with integrated AI for automated detection of explosives, narcotics, and weapons.	TRL 9 (NUCTECH, n.d.)
<b>OD Security</b>	THEIA automatic contraband detection	Driven by ML algorithms, THEIA has been trained using large collections of 'negative' full-body-scan images (i.e. scan images that are free of any contraband).	TRL 7
<b>Rapiscan Systems</b>	InSight / 920CT	A suite of intelligent analytics and AI/ML algorithms integrated into their screening systems, such as the ECAC C3 approved 920CT scanner.	TRL 9 (Rapiscan Systems, n.d.)
<b>RaySecur</b>	MailSecur scanner	A desktop mmWave scanner with AI assistance that provides real-time 3D video to detect threats in parcels.	TRL 9 (complementary) (RaySecur, n.d.)
<b>Smiths Detection</b>	iCMORE	An integrated AI software suite for automatic object recognition of weapons (handguns, parts, knives) and other threats.	TRL 9 (Smiths Detection, 2024)
<b>Tek84</b>	Intercept body scanner	An ultra-low-dose X-ray body scanner that detects metallic and non-metallic threats concealed both on and inside a person.	TRL 9 (adjacent) (Tek84, n.d.)

**2. Machine-agnostic solutions**

Vendor	Key AI product(s)	Description and capabilities	Indicative TRL & source*
<b>Auxilia</b>	AI software add-on	A DL-based software solution designed to be added to existing X-ray machines to automatically detect threats.	TRL 6-7 (vendor information)
<b>Dimensionless Technologies</b>	BaggageAI	A vision-based AI software that analyses X-ray baggage scans to automatically detect threats.	TRL 7 (public announcements)

## 2. Machine-agnostic solutions (continued)

Vendor	Key AI product(s)	Description and capabilities	Indicative TRL & source*
Neural Guard	EyeFox	An AI-based automated threat detection software that connects to the video feed of existing X-ray machines.	TRL 8 (Neural Guard, n.d.)
Pangiam	Project DARTMOUTH	A third-party, open-architecture AI platform, co-developed with Google, to automate the detection of prohibited items in CT scans.	TRL 7-8 (Pangiam, n.d.; Schiphol, n.d.)
SeeTrue Screening	SeeTrue AI	A machine-agnostic AI software solution that connects to existing X-ray and CT scanners for automatic threat detection.	TRL 9 (SeeTrue Screening, 2024)
Synapse Technology (Palantir Technologies)	Syntech ONE	A machine-agnostic AI and computer vision platform designed to be integrated into existing X-ray systems.	TRL 8 (integrated) (US DHS, n.d.; Palantir Technologies, n.d.)

## 3. Supportive or training solutions

Vendor	Key AI product(s)	Description and capabilities	Indicative TRL & source*
Defrag Group and Renful Premier Technologies	Simfox simulator and 3D-printed firearm simulants	A mature and widely used X-ray/CT simulation platform for training and the generation of image data to train and validate AI algorithms.	TRL 9 (enabler) (regulatory acceptance)

Sources: Analysis based on vendor documentation, public reports (CASRA, 2023), and TRL definitions (BRIDGE2HE, 2021).

\* The TRLs listed here are taken from the sources listed. T4T has not been able to independently corroborate these assessments.

## Selected European initiatives and projects

The EU is making substantial investments in research and innovation to advance AI capabilities for security applications. Through funding frameworks like Horizon Europe and the European Defence Fund (EDF), a portfolio of projects is addressing firearms and explosives trafficking.

A review of the EU's research landscape reveals a strategic focus on developing integrated AI-driven solutions. These projects often involve consortiums of academic institutions, technology companies, and law enforcement end users, ensuring that the developed solutions are both technologically advanced and operationally relevant. A key objective is to move technologies from the laboratory to the field, progressing them along the TRL scale. The scale provides an estimate of the maturity of technologies, ranging from TRL 1 (basic principles observed) to TRL 9 (actual system proven in an operational environment) and seven levels in between (BRIDGE2HE, 2021).

Several ongoing or recently completed projects exemplify the EU's commitment to this domain. These include the following:

- CEASEFIRE (Horizon Europe):** This project aimed to develop a holistic, AI-powered system to assist LEAs in weapons counter-proliferation efforts. Its work included an AI model for detecting firearms in X-ray images of parcels, with a goal of reaching TRL 6-7, which involves demonstrating a system prototype in a simulated or real operational environment (Mademlis et al., 2024).
- AIDEDex (EDF):** This project focuses on the automated detection of hidden IEDs and landmines, leveraging AI to analyse data from a wide suite of sensors. Its activities include design and studies, indicating a focus on the lower-to-mid TRL spectrum (EDF, 2022).
- Project Hermes (UNODC):** While not an EU project per se,<sup>7</sup> this UNODC initiative is highly relevant, with the operational objective of countering the trafficking of firearms, their parts, components,

ammunition, and explosives in postal parcels. One of its activities included the development of an X-ray image library that can be used for training and testing AI detection algorithms, though this was a small part of a broader project to strengthen detection capabilities, information exchange, and investigative follow-up. Based on this image collection, the project has developed extensive training resources, including two handbooks, course materials, and online modules. In addition, Project Hermes has developed eight memorandums of understanding between postal operators and customs authorities, supplied partners with ten X-ray scanners and two hand-held explosives detectors, and fostered cooperation that has resulted in controlled deliveries and arrests of perpetrators. The project is now expanding to include express courier companies in its activities (UNODC, n.d.).

- **ANITA (H2020):** This completed project (2018–21) developed a knowledge-based system for analysing online and offline content to fight the illegal trafficking of drugs, counterfeit medicines, and firearms. Its objective to demonstrate the system in “multiple relevant operational environments” suggests it may have reached TRL 6–7 (ITI, n.d.).
- **BAG-INTEL (Horizon Europe):** Running from 2023 to 2026, this project is developing AI-based decision support tools for customs teams at airports, including AI-enhanced detection in scanning images. It aims for “demonstration in real-life use cases”, targeting TRL 7 (BAG-INTEL, 2025).
- **Melchior (Horizon Europe):** This project aims to develop novel technology for detecting concealed goods on individuals, including weapons and explosives. It explicitly aims to demonstrate prototypes in operational environments at TRL 7 (Frontex, 2023).

## Challenges and cross-cutting issues

The successful integration of AI into counter-trafficking operations is not merely a technical challenge: it involves a complex interplay of data availability, standardization, human factors, and a robust regulatory

framework. These horizontal issues must be addressed for the technology to responsibly realize its full potential.

### Data scarcity

As numerous expert reports have emphasized, the single greatest impediment to developing more accurate and robust AI detection models is *data scarcity*. DL models are data hungry, and their performance is contingent on being trained on vast, diverse, and accurately labelled datasets (Vukadinovic and Anderson, 2022).

Images of actual firearms and explosives in real-world baggage and parcels are rare. This makes it challenging to build a training dataset of sufficient size from operational seizures alone, and points to the need for high-quality synthetic training data to refine detection algorithms. As of early 2026, it does not yet appear that any vendors are creating this kind of large-scale synthetic training data.

In addition, the manual labelling of X-ray images by drawing bounding boxes around objects of interest, a process known as annotation, is time consuming and requires trained experts. For security reasons, end users may not wish to farm out this task to external third parties, which keeps processing costs high. Finally, some quantities of data captured by scanners at airports and mail facilities are typically not collected or stored in a way that is accessible for AI training due to operational, legal, and privacy constraints.

AI computer vision developers can potentially circumvent the training data bottleneck by resorting to synthetic training data. One method involves digitally inserting images of threat items into benign scans. This approach is not a substitute for large ‘real-world’ training datasets. Algorithms trained on synthetic data alone can sometimes learn to detect the subtle artifacts of the insertion process rather than the threat itself, leading to a domain shift problem where performance drops when applied to real-world images (Vukadinovic and Anderson, 2022). Combining real-world and synthetic data is thus critical to calibrating performance while maintaining low false-positive rates. Initiatives to create large, standardized libraries of real X-ray images to improve the training of AI models would be beneficial in this domain.



**Figure 4. Leidos scanning system**  
(Source: Leidos)

### Performance evaluation standards

The European Union does not have a stand-alone APIDS regulation, but APIDS are covered under the European Civil Aviation Conference (ECAC) Common Evaluation Process (CEP) for security equipment. EU Decision C(2015) 8005 defines the EU APIDS performance standards and the testing methodology that must be followed for any APIDS intended for use in EU airport security equipment (European Union, 2015). The ECAC CEP framework is incorporated into EU aviation security law by Regulation 2025/41 (European Union, 2025).

The complete ECAC standards are classified but the authors have reviewed a summary that indicates a minimum algorithm detection probability requirement across a set of different threats, including firearms, and a false alarm rate for high-risk threats like firearms and explosives. They also require testing institutions to ensure that test sets exhibit a variety of physical orientations and levels of shielding (occlusion) in images that also feature a variety of clutter, as well as image artifacts and noise. Certification for the AI software is given for a particular hardware system with which it is to be integrated, and specifies whether the system is approved for assisted systems (Level 1) or fully automated ones (Standard 2) (European Union, 2023).

Five national testing facilities conduct APIDS ECAC performance testing: France, Germany (2), the Netherlands and the United Kingdom (ECAC, 2025).

As of February 2026, only the SeeTrue detection software running the Analogic ConneCT and Rapiscan 920CT EDSCB machines has been ECAC CEP certified for APIDS Level 1 (ECAC, 2026). Previously, SeeTrue had received a certification from the Dutch national authority in April 2025 (PR Newswire, 2026). Meanwhile, Smiths Detections' iCMORE HI-SCAN 6040 configuration was certified by the German Federal Police Technology Centre for use in German airports (Airport Technology, 2025).

It was not possible for Tech 4 Tracing to review the types and variety of firearms that are included in the ECAC CEP testing datasets, or to determine whether the dataset is fixed or testing institutions have any freedom in selecting firearm makes, models, components, and material types. It would be important for national firearms trafficking experts to be able to periodically review these specifications. Indeed, with the significant shifts in trafficking patterns discussed above (pp. 2–3), is it important for these testing datasets to be responsive and evolve to meet those changes. This may be mainly a question of ensuring that law enforcement trafficking expertise routinely informs the algorithm certification process.

### Decision-support systems vs. full automation

The automation of decisions and actions can take place at a variety of levels. Parasuraman et al. (2000) propose a 1–10 ranking system for describing automation. At level 1, a system provides no support to aid an operator. At level 3, a system narrows the selection down to a few options. In a level 10 system, the AI or machine–software solution decides everything and acts autonomously, without human involvement in the decision chain. But while a human may be required for follow-up support to a fully automated system, a trained technician is not required.

For package screening, fully automated (level 10) systems are years away. A more feasible, limited decision-support system at levels 2–5 will aid human screeners in their duties, but they will still ultimately need to be technically proficient, trained, and certified. As AI solutions become more widely adopted, however, they will ultimately improve and outperform trained operators,

at which time the screener's role should also transform and evolve. The screener's task will then shift from a demanding visual search to one of alarm investigation, human interaction, and verification. But for the foreseeable future, the overall effectiveness of the screening process will depend not only on the performance of the detection technology, but also on the seamless functioning of the human-machine team.

Among nascent technologies, trust and expectations are quickly gained or lost based on early integration and trials. Early systems that continuously generate false alarms will cause operators to ignore or quickly dismiss flagged items (Vukadinovic and Anderson, 2022). Conversely, a system that is perceived as overly reliable, or ones where commercial solutions providers have overstated their systems' capabilities, could lead to over-trust and complacency, and operators may fail to spot threats missed by the automated system.

To minimize these growing pains, comprehensive training, clear operational protocols, and an intuitive user interface are important safeguards to help transition the industry towards more automated systems. As highlighted in Huegli et al. (2025), even with the introduction of modern APIDS, a well-trained and vigilant human operator will always remain a key component of an effective security-screening process.

## The regulatory and ethical landscape

The use of AI in law enforcement and border management is subject to a rigorous legal and ethical framework embodied at its highest level in the EU by the AI Act. This landmark regulation adopts a risk-based approach and some AI systems intended for use in security screening may be classified as 'high-risk' (Europol, 2024). A 'high-risk' designation would trigger a series of demanding obligations for both the developers (providers) and users (deployers) of these systems.

A non-exhaustive set of key obligations would include the following:

- **risk-management systems:** a continuous process to identify and mitigate risks throughout the AI system's lifecycle;
- **data governance:** the use of high-quality, representative, and unbiased training, validation, and testing data;

- **technical documentation:** comprehensive documentation to allow authorities to assess compliance;

- **human oversight:** a system designed to be effectively overseen by humans, who can intervene or disregard the AI system's output; and

- **accuracy, robustness, and cyber security:** a high level of performance and resilience against errors and malicious attacks.

Implementation and oversight of the EU AI Act are continuing to roll out, and by mid-2026 there should be more clarity about what types of AI use cases in the security and border control space are considered 'high risk' and what steps and internal controls would help avoid such a designation. Future discussions will also take place in the context of the European Commission's new Digital Omnibus, launched in November 2025, which aims to boost digital and AI innovation and establish a more graduated approach to enforcement of the AI Act (European Commission, 2025).

At present, it is not obvious that APIDS would warrant an automatic 'high-risk' designation, given that natural persons and their data are typically not targets and that training data is—or should be—generated in a highly constrained and controlled manner. However, experts advise that providers should take the AI Act's obligations seriously even if they are not currently obliged to follow them, because their applicability may change in the future and they represent practice standards worth striving for. Either way, law enforcement procurement and deployment processes for AI-enhanced systems should already include rigorous due-diligence requirements to ensure compliance with relevant rules and regulations.

## Conclusions and the way forward

The integration of AI into the fight against firearms and explosives trafficking represents a critical and necessary evolution for European law enforcement and customs authorities. The technological landscape is maturing rapidly, with commercial APIDS starting to offer tangible improvements in detection capabilities at key interdiction points. The EU's strategic investment in research and innovation is fostering the

development of next-generation solutions aimed at tackling the multifaceted nature of this threat.

As this assessment makes clear, however, the path to widespread, effective, and responsible deployment is fraught with challenges. The promise of AI can only be fully realized if the foundational issues of training and benchmark data, standardization, human factors, and effective governance are addressed with the same vigour as the technological development itself.

The state of play can be summarized by four overarching findings. First, AI detection in X-ray screening is operationally viable, but data constrained. Some technologies have shown effectiveness, but the full potential is limited by the lack of both large-scale, real-world training data and tailored synthetic data. Second, the EU is building a strong R&D foundation. Projects have attempted to create the blueprints for the integrated, AI-driven security platforms of the future, but these are not yet off-the-shelf solutions. Third, the human element remains indispensable. Currently, AI detection is a tool to augment, not replace, the human operator. The success of AI-assisted screening hinges on effective human-machine teaming. Fourth, the EU AI Act sets a high bar for compliance for AI-enhanced APIDS, especially what it considers to be 'high risk', which should be anticipated and planned for.

For high-level EU arms control and security policymakers, the current state of play calls for strategic actions to steer the development and deployment of AI in a direction that maximizes its security benefits while upholding European values. These could include the following:

■ **Championing a European data initiative for security AI:** The most impactful action the EU can take is to address the data-scarcity bottleneck. This requires moving beyond individual projects and establishing a formal, funded, and coordinated European data initiative. Building on the groundwork of Project Hermes, this initiative should aim to create a large-scale, legally compliant, and ethically managed reference library of X-ray and other sensor data for training and testing AI. This would be a strategic asset for European security, fostering innovation and reducing reliance on non-EU data sources.

■ **Continually refine testing and certification standards:** Current EU APIDS standards, and particularly testing datasets, need to reflect actual firearms threats, which continue to evolve. It will be important to ensure that, as individual firearm parts and 3D-printed components become more prominent in trafficking seizures generally, these and other objects get included in benchmark testing datasets. That will help ensure that the algorithm certification process remains fit for purpose and responsive to the real-world threats. Standards applied to other eventual X-ray systems, such as for parcel post, should follow suit.

■ **Fostering public-private and inter-agency collaboration:** The EU should create and support platforms for structured collaboration among law enforcement end users, customs authorities, academic researchers, and commercial technology developers. This will ensure that R&D is aligned with operational needs and that best practices are shared across the EU. The Europol Innovation Lab and the EMPACT platform are key vehicles for this collaboration.

■ **Investing in the 'human in the loop':** Together with technological investment, resources must be allocated to understanding and optimizing the human-machine interface. This includes funding research into human factors, developing new training curriculums for operators working with AI systems, and establishing clear doctrines for the use of AI-generated alerts and intelligence.

■ **Promoting 'responsible AI by design':** The EU should actively support and enforce the principles of the EU AI Act. Procurement criteria for law enforcement and customs services should explicitly require adherence to the principles of fairness, accountability, transparency, and explainability. This will not only ensure legal compliance but will also ground the public trust that is essential for policing in a democratic society.

By taking these strategic steps, the EU can guide the evolving use of AI in security systems and operations, ensuring that it becomes a powerful, reliable, and trustworthy tool in the enduring effort to counter the trafficking of firearms and explosives. ■

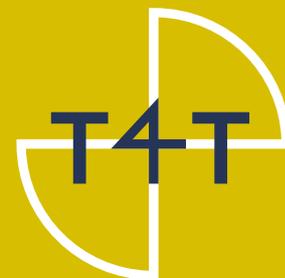
## Abbreviations and acronyms

AI	artificial intelligence
APIDS	automated prohibited items detection system(s)
CEP	Common Evaluation Process
CT	computed tomography
DL	deep learning
DR	detection rate
ECAC	European Civil Aviation Conference
EDF	European Defence Fund
EMPACT	European Multidisciplinary Platform Against Criminal Threats
EU	European Union
FAR	false alarm rate
IED	improvised explosive device
JRC	Joint Research Centre
LEA	law enforcement agency
LLM	large language model
ML	machine learning
mmWave	millimetre wave
NATO	North Atlantic Treaty Organization
OEM	original equipment manufacturer
PMF	privately manufactured firearm
R&D	research and development
SOCTA	Serious and Organised Crime Threat Assessment
T4T	Tech 4 Tracing
TRL	technology readiness level
UNODC	United Nations Office on Drugs and Crime

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## About Tech 4 Tracing

Stichting Tech 4 Tracing Europe (Tech 4 Tracing) is a non-profit AI computer vision lab based in the Netherlands that develops tools and assets to address the proliferation of illicit weapons, explosives, and unexploded ordnance in crime and conflict-affected contexts and advises policymakers on the safe and secure deployment of AI for counter-proliferation efforts.

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## Notes

- 1 Vukadinovic and Anderson (2022).
- 2 INTERPOL-UNICRI (2020).
- 3 UNODC (2024).
- 4 Communication with the Dutch national police coordinator for illegal weapons, October 2025.
- 5 Communications with EUROPOL weapons and explosives team members, August 2025.
- 6 Standard X-ray systems use a short burst of particles to create a single 2D image; CT systems create a series of X-ray images taken from multiple angles that are then processed by a computer to create cross-sectional (slice) images.
- 7 Project Hermes is funded by the UN Multi-Party Trust Fund, which pools contributions from France, Germany, the Netherlands, Sweden, and the United Kingdom.