

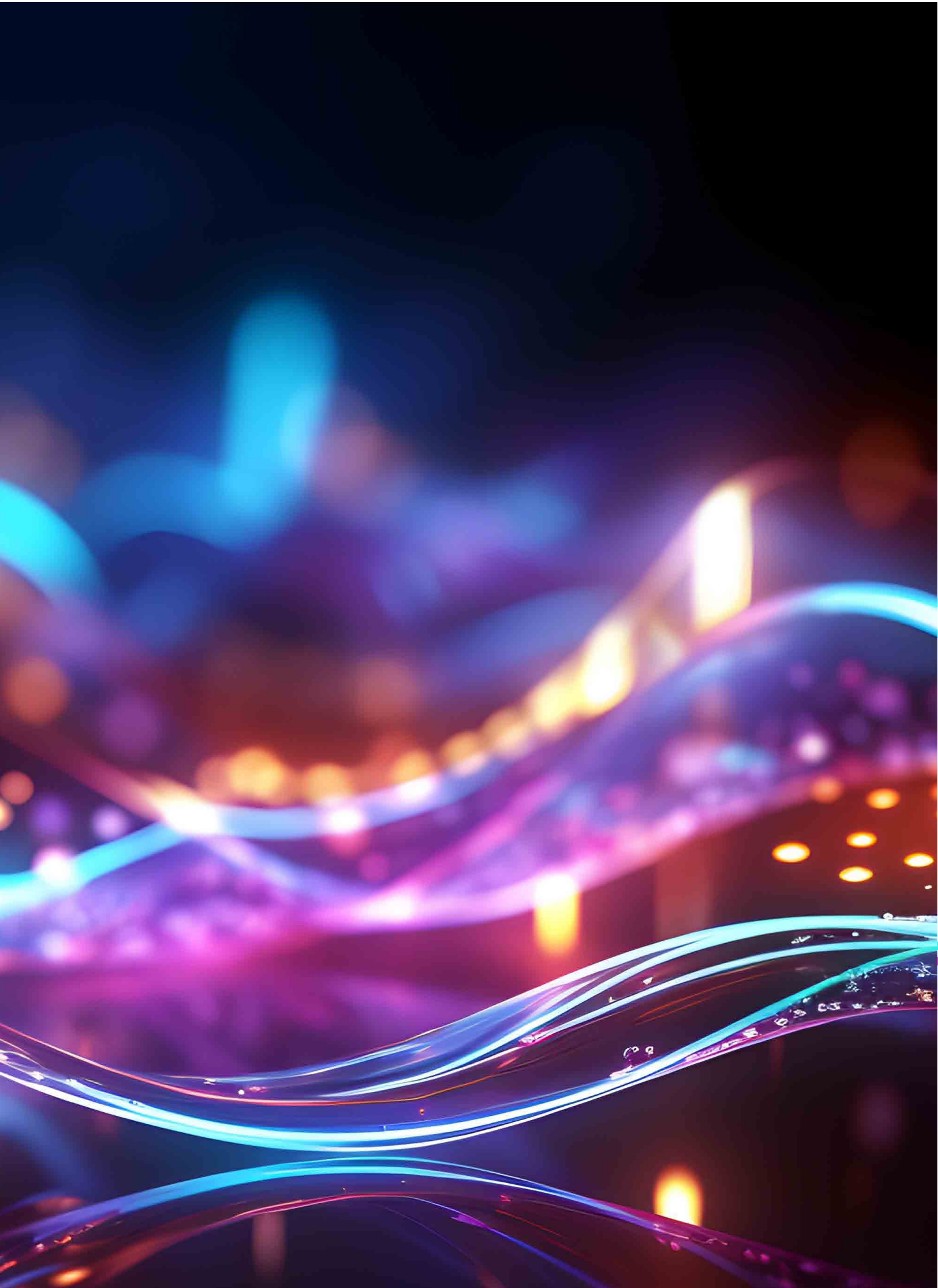
TECHNOLOGY

HORIZON

SCANNING



EMERGING TECHNOLOGIES ARE RESHAPING THE BORDER LANDSCAPE



The evolving technology landscape is reshaping long-standing trends and creating new paradigms in border management operations. In the face of this dynamic landscape, integrating advanced tools derived from emerging technologies in operations, strategic planning, and innovation initiatives is essential for secure and efficient borders. As such, coupling emerging technologies with the right capabilities and maintaining situational awareness of the evolving technology landscape can transform the security and management of borders. Situational awareness of emerging technology and rapidly evolving global innovations is integral to Frontex's core mandate.

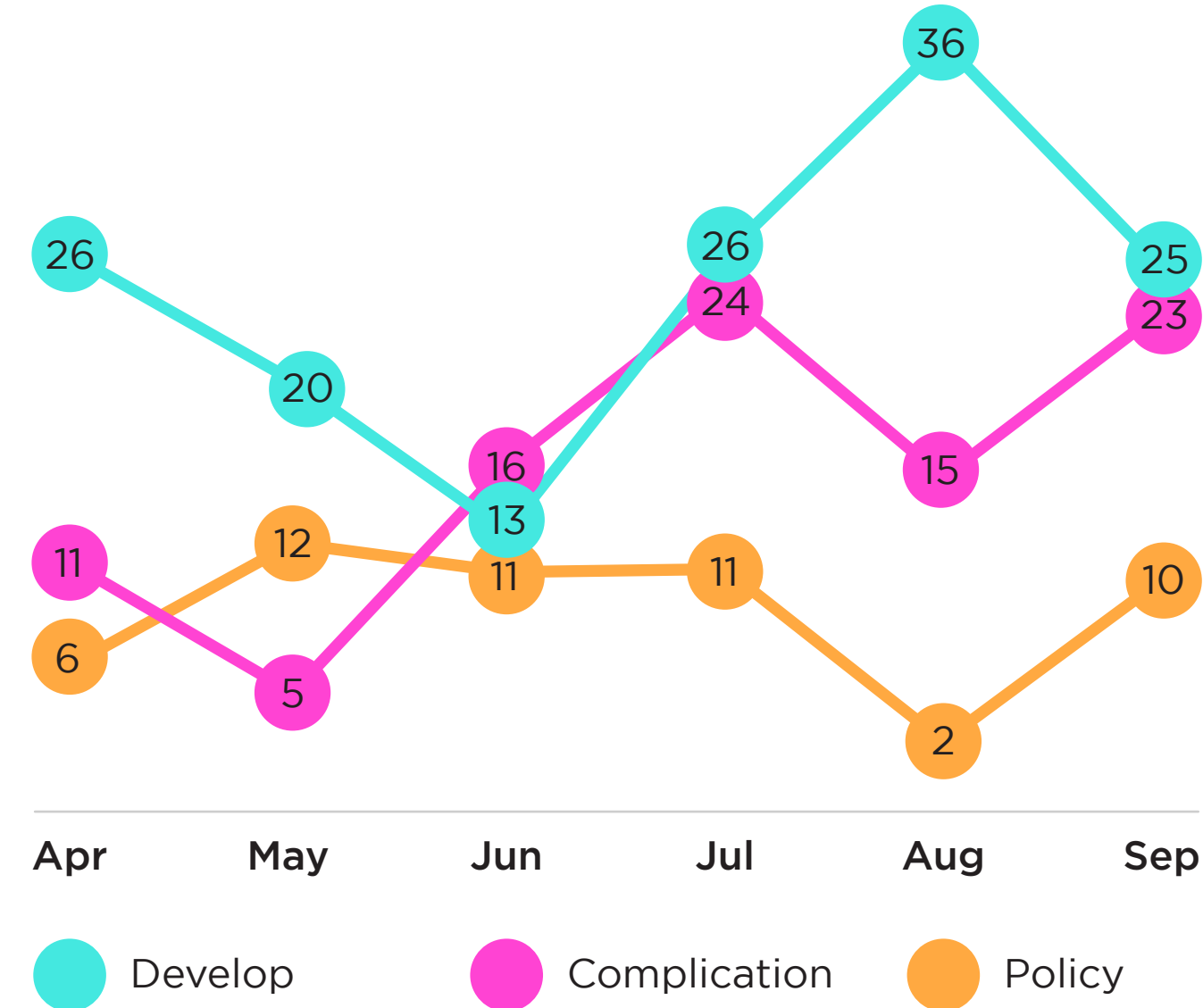
Leveraging advanced AI-powered tools can be a powerful mechanism to maintain this awareness, mitigating resource-demanding, time-consuming manual efforts, and enabling decision-making. Through AI, the acceleration of big data and analytics, while harnessing human capabilities and intelligence sharing, can support Frontex in predicting and responding to existing and emerging challenging border situations. This booklet was produced in the context of Frontex's Technology Horizon Scanning activities focused on selected Key Enabling Technologies expected to have emerging impact in border security.

EMERGING TECHNOLOGIES ARE RESHAPING THE BORDER LANDSCAPE

TRENDS IN BORDER SECURITY APPLICATIONS OF EMERGING TECHNOLOGIES - SURFACED THROUGH HORIZON SCANNING

The seven trends (6G, growing AI, AI-powered data analysis, autonomous systems, new advanced computing methodologies, new regulation impacting augmented reality, XR and meta-universe momentum) represent the most prevalent data related to the intersection of technology and security use cases during this period, followed by a deep dive horizon scan on XR due to its current and future outlook for security applications. Trends were sourced using leveraging SensingBridge™, an AI-driven platform and its sensing capabilities. The overarching theme across the engagement is depicted in Figure 1 and highlights tensions in innovation, risks, and regulation. Signals are defined categories tracked by the platform that represent actions taken and are used to analyse the dataset to identify patterns. “Development” refers to all data mentioning technology innovation, “complication” refers to all data expressing risks, and “Policy” refers to data surrounding legislation or policy changes.

Figure 1: Signals across engagement



Of the 6 signal types, (Develop-Complication-Policy-Investment-Collaboration-Hiring), Develop, Complication and Policy were the most prominent. Periods of technological advancement were often followed by regulatory pushes to correct for risks seen in implementation. As Frontex seeks to innovate to achieve its mission, it will be important to continuously maintain awareness of the potential risks associated with emerging technologies and to monitor emerging policies to inform implementation.



EMERGING TRENDS

BORDER SECURITY APPLICATIONS OF EMERGING TECHNOLOGIES SURFACED THROUGH HORIZON SCANNING

Trends in border security applications of emerging technologies
- surfaced through horizon scanning

The seven trends below represent the most prevalent data related to the intersection of technology and security use cases during this period, followed by a deep dive horizon scan on XR due to its current and future outlook for security applications. The overarching theme across these trends highlighted tensions in innovation, risks, and regulation. Periods of technological advancement were often followed by regulatory pushes to correct for risks seen in implementation. As Frontex seeks to innovate to achieve its mission, it will be important to continuously maintain awareness of the potential risks associated with emerging technologies and to monitor emerging policies to inform implementation.

6G ENHANCES BORDER SURVEILLANCE BUT SPARKS PRIVACY AND SECURITY CONCERNS



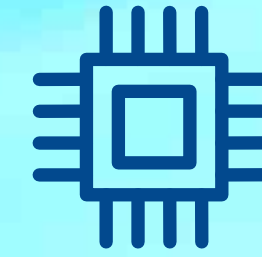
The EU announced innovation opportunities to drive forward emerging 6G, with the "TARGET-X" 6G research project that funds over 100 studies in 6G implementation. It promises near-seamless connections between XR devices and the metaverse with faster speeds and lower latency than 5G. Additionally, 6G's increased bandwidth can support hyper-realistic digital twins and improve IoT functionality, especially in remote areas. It is set to launch in 2030 and currently in the research and planning phase.

Potential risks

6G raises privacy and security concerns as the new network will bring large amounts of network traffic that will further complicate data encryption. 5G launch serves as a case study of privacy issues in ultrabroadband, with numerous cyber-attacks having exploited the dramatic expansion of bandwidth and increased number of connected devices. 6G technology holds promise for advancing IoT and XR capabilities, and the shortcomings of 5G launch underscore the need for enhanced security measures to successfully launch the new network.



AI IS GROWING BUT SO ARE THE CONCERNS AROUND PRIVACY



AI is being integrated into law enforcement settings sectors such as biometrics and facial recognition for improved performance. Numerous countries around the world are using facial recognition technologies (FRTs) and remote biometric identification devices as surveillance technology in law enforcement settings. Biometric technologies have the potential to enhance surveillance capabilities and reduce time spent on identifying fraudulent documents and identities.

Potential risks

Privacy concerns around AI and detection technologies have emerged, and the European Commission has amended the AI Act to regulate facial recognition technologies more comprehensively, including data interoperability and storage restrictions. The EU has emphasized ethical AI and privacy regulations with a voluntary ethical AI pact with Google. However, there's a tension between innovation and regulation, as other countries embrace AI for surveillance technologies (biometric identification, facial recognition, chatbots and advanced digital assistants). The EU's role is crucial in shaping AI development while safeguarding privacy and security through GDPR-based guidelines and security-conscious innovation.



AI-POWERED DATA ANALYSIS HOLDS POTENTIAL TO ADVANCE HUMAN TRAFFICKING MITIGATION TACTICS



There is potential for governmental authorities to adopt AI-powered solutions to aid in human trafficking mitigation efforts. AI avatar technology can help maintaining anonymity of victims during human trafficking investigation interviews with an entirely new AI-generated face and voice. An additional technique can help address human trafficking: the usage of AI-powered analytics guided by computer vision in processing identification documents at the border.

AI was mentioned in 17% of all data detailing potential complications and risks

AI tools was a top mentioned technology term with human trafficking over the engagement. 20% of all data mentioning human trafficking mentioned AI tools

Potential risks

While the use of AI for border surveillance brings operational efficiencies, risks such as AI bias when utilising computer vision technology for processing identification documents cannot be overlooked. Computer scientists are looking for ways to mitigate bias to avoid skewed results from AI, noting that accounting for bias is an ongoing process, not a one-time fix.



AUTONOMOUS SYSTEMS AND AI ADVANCEMENTS HOLD PROMISES FOR ENHANCED SURVEILLANCE



Recent advancements show potential for innovations in autonomous border surveillance. New systems include aerial (Unmanned Aerial Vehicles - UAVs), ground (Unmanned Ground Vehicles - UGVs) and surface (Unmanned Surface Vessels - USVs) devices. Potential Unified Autonomous Driving (UniAD) capabilities as well as AI-powered systems for automated surveillance, leveraging beyond-line-of-sight (BLOS) communication can expand their operational range. This would extend capabilities for monitoring mountainous areas and seas.

Detection technologies like imaging and sensors, often paired with unmanned systems, are proving useful to detect cross-border crime. UAVs, UGVs and USVs can further increase maritime security and expedite search and rescue missions. The European Commission's new strategy to mitigate drug trafficking calls for advanced technologies in maritime security. UAVs, UGVs and USVs can further increase maritime security and expedite search and rescue missions. Unified autonomous driving vehicles can also be equipped with additional surveillance technology, such as smart sensors and robotic cameras, to enable surveillance capabilities.

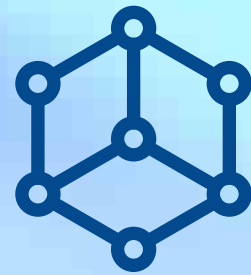
Autonomous Systems mentions doubled over the course of the Engagement. In September, 30% of all technology mentions were autonomous systems

Potential risks

Safety and privacy considerations must be examined before considering adoption of AI powered systems. Autonomous systems and detection technologies are two technology areas that can enhance border security but raise ethical and security concerns. The market for unmanned systems is growing and border guard authorities must consider security risks of adversarial unmanned systems with the same capabilities that can be used for weapons, acquiring intelligence, and monitoring missions. A notable instance of plans to safely implement AI powered systems involves the completion of the EU funded Flying Forward 2020 program, which demonstrated the viability of AI powered drones in urban settings along with a path to legally compliant commercialisation of AI-powered systems.



NEW ADVANCED COMPUTING METHODOLOGIES REVOLUTIONIZE BORDER SECURITY



Technology with a lower readiness level (digital twins, computer vision, and autonomous systems) offer additional tools to combat the increasing global issue of human trafficking. Digital twins technology offers advanced insights into logistical challenges thanks to one-to-one replica of activities taking place. Computer vision systems, such as MoTok from UC Berkeley, enhance surveillance accuracy with less machine learning required. These systems contribute to adapt to emerging trafficking tactics by enhancing surveillance capabilities.

Potential risks

These innovations can improve operational efficiency and safety, making them crucial for security authorities as they reach higher technology readiness level. However, it is vital to be aware of AI bias when using these technologies to ensure accuracy and fairness with their usage. It will also be crucial for governmental authorities to responsibly manage the AI lifecycle, train and educate personnel on AI development, and create a culture of accountability to ensure the technology is utilized ethically in implementation.

NEW REGULATION IS REVEALING CHALLENGES IN AUGMENTED REALITY



The European Union's Digital Services Act (DSA) addresses regulation is crucial as it sets the stage for managing challenges in the emerging unlimited reality space. The DSA's effectiveness in regulating social media offers valuable insights for potential unlimited reality regulations. Monitoring the DSA's impact is vital for shaping future regulatory approaches in unlimited reality, which can have significant applications, such as enhancing border guard training through AR, VR, and MR technologies.

Across the first quarter, several new pieces of EU-based legislation mentions increased by close to 89%.

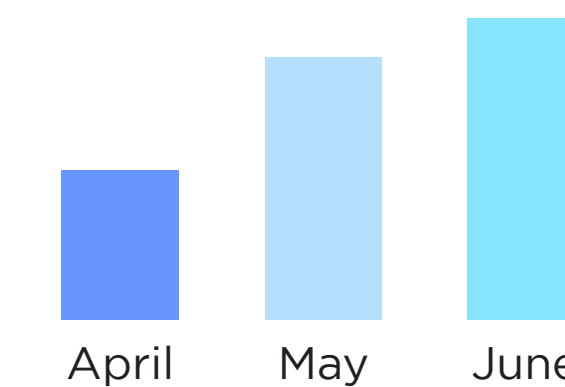


Figure 2: Policy/Government developing policy



XR AND METAVERSE GAIN MOMENTUM BUT REQUIRE PROPER CYBER SECURITY



XR and Metaverse technologies are advancing. XR enabling technologies, such as 5G and cloud computing allow an increased pace of data transfer to the cloud, processing speeds, and formation of virtual images, as well as a higher numbers of participants in multiplayer XR experiences. This allows for more sensors and cameras to be used in an XR environment, allowing them to become more collaborative and interoperable across organizations and platforms. The metaverse will be a convergence of the digital, physical, and interpersonal worlds; producing accurate, responsive, and interactive digital renderings and simulations of real-world places/objects/systems based on data collected through IoT devices that is quickly processed by cloud or edge computing using AI.

XR offers direct benefits, such as enhancing training and preparedness, reducing language barriers, and streamlining data handling. XR can be used to improve real-time situational awareness and communications between command centres and field personnel. XR cloud will allow mass creation and distribution of AR content by offering a cloud-based digital copy of the real world where developers and non-developers alike can build AR experiences and applications using frameworks rather than starting from scratch. AR, VR, and MR-based training will benefit border guard authorities by decreasing operational risks and costs while improving personnel competency.

Potential risks

XR, while considered a maturing technology, still faces a myriad of uncertainties. Its market is in a state of development. At the core of this market is a relatively underdeveloped regulatory landscape that may fundamentally alter the way in which industry and consumers interact with the technology. Accordingly, governments and businesses will need to stay engaged and abreast of changes in the XR ecosystem so that they can adapt their practices accordingly and transparently to ensure ongoing compliance and public trust in their use of XR technologies.

Although XR-cloud systems may be the future of XR, they may also increase cybersecurity risks. Homomorphic encryption is one of the most promising cryptographic techniques that allows computations to be performed directly on encrypted data. This enables encrypted data sharing that protects the data while still allowing for analytics to be run against said data. Using homomorphic encryption in cloud based XR solutions may act as a bulwark against the myriad of cybersecurity threats. XR and the metaverse require cybersecurity safeguards to prevent data breaches and cyberattacks. To ensure safe usage, regulations and employee training in data management are essential, especially as the EU prepares for increased traffic in the metaverse.



NAVIGATING THE FUTURE STATE OF EXTENDED REALITY

NEAR-TERM OUTLOOK (0-5 YEARS)

Feature

Benefits

Higher-resolution displays with high refresh rates will roll out, reducing latency issues and cybersickness, which is often a result of display lags.

More accurate and usable XR experiences

Advancements in sensors and cameras will tie physical and virtual environments together more seamlessly.

More realistic experiences in virtual environments

Sensors can more accurately track user's movements and create a sense of presence in a virtual environment,

Integration of AI into XR systems

More realistic environments that provide users with more personalized experiences

5G and cloud computing allow an increased pace of data transfer to the cloud, processing speeds, and formation of virtual images, as well as a higher numbers of participants in multiplayer XR experiences and allow for more sensors and cameras to be used in an XR environment.

Increase of the level of detail and interactivity.



NEAR-TERM OUTLOOK (0-5 YEARS)

Feature

Benefits

Cloud computing for XR replaces the need for powerful hardware, data storage, and image processing requirements. Faster computational power that can render complex virtual environments, process large amounts of data, and provide real-time feedback to users.

More scalable, cost-effective and accessible to users around the world. Cloud computing will also simplify the development of XR applications for users worldwide.

XR cloud will offer a cloud-based medium that will act as a digital copy of the real world where developers and non-developers alike can build AR experiences and applications using frameworks rather than starting from scratch.

Mass creation and distribution of XR content

XR-cloud systems may be the future of XR, they may also increase cybersecurity risks. Homomorphic encryption is one of the most promising cryptographic techniques that allows computations to be performed directly on encrypted data.

More secure XR systems

While Mixed Reality (MR) is a core component of the XR environment today, it is one of the most underdeveloped aspects of the landscape. The next several years will also see a more robust and established MR market.

More robust and established mixed reality market

LONG-TERM OUTLOOK (5+ YEARS)

XR technologies begin to integrate with the human body. Brain-computer interfaces (BCIs) are expected to hit the XR market over the next decade to support even further immersion.

BCIs aim to replace screens and physical hardware entirely (wireless brain chip, smart contact lenses).

XR environments may become more collaborative and interoperable across organizations and platforms in the long term via an integrated network of XR simulations.

The metaverse will be a convergence of the digital, physical, and interpersonal worlds, producing accurate, responsive, and interactive digital renderings and simulations of real-world places/objects/systems based on data collected through IoT devices that is quickly processed by cloud or edge computing using AI.

IN 10+ YEARS, ANALYSTS PREDICT 3 POSSIBLE LONG-TERM OUTCOMES

- The metaverse becomes a specialized platform for select use cases but never becomes a general-purpose platform
- There will never be a single metaverse, but a handful of major players that compete for market share
- The metaverse is formed as an open, interoperable interface through which stakeholder and users across all industries conduct their daily activities

Deloitte China (2022), The Metaverse Overview: Vision, Technology, and Tactics, available here



XR OPPORTUNITIES



XR OPPORTUNITIES FOR BORDER GUARD AUTHORITIES

Border guard authorities face many challenges as they operate in an era of unprecedented and increasingly complex currents that have arisen in the wake of a global pandemic, a looming climate change crisis, and an AI/technology revolution. Frontex, like other organizations involved in border and coast guard operations, has several compelling reasons for exploring the adoption of XR technologies. XR can offer direct benefits, such as enhanced training and preparedness and reducing language barriers. Additionally, data visualization and analysis enabled enhanced surveillance will provide rapid response and cross-border coordination.

XR TRAINING

AR/VR/MR-BASED TRAINING

AR, VR, and MR-based training may significantly benefit border guard authorities by decreasing operational risks and costs while improving personnel competency.

PERSONNEL PERFORMANCE MONITORING

XR can be used to measure officers' training performance and aptitude in order to gauge trainee readiness for in-field operations.

XR BASED-TRAINING: CROSS-BORDER CRIMES

XR can be used to improve the quality of border guard trainings on fighting cross-border crimes such as human trafficking and the smuggling of drugs, firearms, stolen cars, and counterfeit goods.

LANGUAGE LEARNING

XR solutions can provide language training modules designed for border guards to learn how to communicate with migrants who speak different language. XR innovation can create significant efficiencies in border guards training and operations (thanks to real-time language translations) in migrant processing, in turn expediting throughput.

SEARCH AND RESCUE TRAINING

XR can be used to train personnel for search and rescue operations, particularly in the maritime domain.

SITUATIONAL AWARENESS

COMMAND CENTRE & IN-FIELD

XR can potentially be used to improve real-time situational awareness and communications between command centres and field personnel. e.g. by developing

- 1 an intuitive and user-friendly interface for border security tools;
- 2 cloud-based decision-support services and tools for field and C2 operators;
- 3 and the needed communication infrastructure to accomplish border control and security tasks

REGISTERING TRAVELLERS, MIGRANTS, AND CUSTOMS DECLARATIONS

AR glasses can further enhance operational processes by displaying documentation directly in border guards' line of vision.

AR FOR BORDER LINES MARKING

Border personnel can make use of AR technologies in regions where surveying and making border markers and lines on the ground is difficult. Hence, border lines and markers can change due to various factors.

In areas with challenging ground conditions, border personnel can employ AR technologies to identify border markers.

CROSS-BORDER CRIMES

AR glasses can use facial recognition technology, voice print, and backend databases to compare individuals at the border with watchlists of known criminals, terrorists, or other persons of interest.

AR glasses could aid in instantaneous identification and enabling officers to take appropriate action and prevent the entry of potential threats if matches are found.



XR IMPLEMENTATION CONSIDERATIONS

XR, while considered a maturing technology, still faces a myriad of uncertainties. At the core of this market is a relatively under-developed regulatory landscape that may fundamentally alter the way in which industry and consumers interact with the technology. Accordingly, governments and businesses will need to stay engaged and abreast of changes in the XR ecosystem so that they can adapt their practices accordingly and transparently to ensure ongoing compliance and public trust in their use of XR technologies.

XR IMPLEMENTATION CONSIDERATIONS

PRIVACY AND REGULATION

XR amplifies existing privacy concerns, creating novel, and often more invasive issues for user privacy due to the scope, scale, and sensitivity of the information they collect. Industry leaders, such as Intel, have called for data protection rules to extend to virtual environments and digital objects, however, such rules have yet to fully manifest and their future remains unclear.

TURNKEY SOLUTIONS VS. CUSTOM-BUILT SOLUTIONS

While law enforcement uses turnkey solutions, other governmental authorities prefer custom-built XR systems, designed either by vendors or in-house. Custom solutions offer control but are costly and time-consuming requiring extensive planning for integration with other systems. However, for larger organisations operating across numerous locations, custom solutions can be more cost-effective than pre-built, turnkey solutions. For Frontex, turnkey solutions may be suitable for general use cases, while custom-built solutions will likely be required in the near-term for organisation-specific or border-specific use cases.

CYBERSECURITY

Border guard authorities should have robust infrastructure in place to secure the communication and data stored by XR systems. Security practices of the XR solution's vendor should be assessed before purchasing and implementing robust monitoring (network, logs). Users should train for abnormal behaviour on the XR devices and/or applications and develop an incident response plan. This way border guard authorities can enhance the cybersecurity posture of their XR systems and protect sensitive data and infrastructure from adversaries.

LEGACY SYSTEMS

Legacy systems may have limitations in terms of processing power and memory which may hinder the seamless integration of XR solutions. XR technologies require advance hardware and sensors that may not be compatible with legacy systems. Addressing these challenges requires a comprehensive approach that considers technical, operational, and organizational aspects. The approach should involve planning and collaborating with IT departments and XR solution vendors, as well as a phased implementation strategy that allows for testing, fine-tuning, and gradual adoption of XR technologies alongside legacy systems.



CONCLUSIONS

With the rapid evolution of emerging technologies, border guard authorities face the ongoing challenge of aggregating, synthesising, and understanding the implications of technology developments and associated risks and regulations. As seen by the rapid rise of AI technologies in 2023, technology developments can occur quickly and have extreme implications for organizations and their leaders. To remain responsive in a changing environment, particularly when there are security implications, it is beneficial to utilise a structured sensing process paired with advanced aggregation methods. These processes and methods equip professionals to remain aware of technology trends, emerging developments, challenges, gaps and needs that could impact their governmental authorities.

The trends described above emerged through the process of horizon scanning, which is the process of gathering and analysing information to understand and adapt to changes in the environment. In a technology context, horizon scanning serves as a repeatable, efficient, always-on process that enables organizations to stay agile and responsive to evolving innovations in technology. Technology scouting is an additional discipline that provides detailed, targeted identification of solutions, trends, and/or vendors to fill near-term technology needs. Paired together, horizon scanning and technology scouting provide a high-level view of the future and an operational roadmap to adapt to changing trends. Research can be made more efficient through the facilitation of conversations across the organization, bringing together program leads, researchers, and subject matter experts to determine the best methods to implement innovations.

Advanced technology horizon scanning capabilities can provide Frontex the foundation to make operational decisions about resource allocation, workforce development, market partnerships, acquisitions, and others. Assessing and evaluating a large dataset of diverse sources provides organisations with confidence in decisions about key operational choices. With a robust scanning process, leaders can trust that data is presenting a thorough analysis of the environment to allow them to be more efficient and prepared to meet the challenges of the ever-changing global landscape.



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