QUANERGY 3D LIDAR SOLUTIONS REDEFINING THE PHYSICAL SECURITY OF CRITICAL INFRASTRUCTURE

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INTRODUCTION AND EXECUTIVE SUMMARY

3D LIDAR'S UNIQUE CAPABILITIES TO TAKE PHYSICAL SECURITY OF CRITICAL INFRASTRUCTURE TO THE NEXT LEVEL

Physical security, in general, and more specifically, perimeter intrusion protection of critical infrastructure sites such as airports, data centers, warehouses and distribution centers, and utilities such as energy substations and water plants are becoming increasingly important against a background of rising threats in the form of theft, protests, sabotage, terrorism, and outright war. Physical security relates to both persons or vehicles entering guarded areas and objects thrown or passed across perimeter boundaries. Additionally, cyberattacks are often preceded by physical breaches, making intrusion detection an important tool in the fight against cyberthreats.

Current physical security technology solutions based on cameras and/or radar fall short in terms of effectively tracking intruders and generating too many false alerts, resulting in costly alarm fatigue. These Two-Dimensional (2D) legacy technologies are not accurate enough, and perform poorly in low light and adverse weather conditions, resulting in missed events and high cost of ownership. This is where Three-Dimensional (3D) Light Detection and Ranging (LiDAR) technology comes in, offering robust, reliable, and high-precision tracking through a mesh architecture at an overall lower cost of ownership, allowing

managers of critical infrastructure to increase the effectiveness, while reducing the cost of their guard services.

LiDAR can potentially be deployed as a standalone physical security solution, replacing legacy camera-based systems, but it is more typically installed as a complementary technology in two-stage perimeter defense, enhancing the performance of imaging analytics already in place. More specifically, 3D LiDAR makes existing video-based solutions more effective because it enables existing Pan-Tilt-Zoom (PTZ) cameras to point to where the actual threat is coming from. PTZ cameras get confused by moving objects and, therefore, often fail to continuously track potential threats. In other words, 3D LiDAR helps cameras perform better.

While LiDAR is best known as the sensor technology enabling driverless cars and robots, it is clear that it also has the potential to move the needle in other markets and segments, taking physical security of critical infrastructure to the next level.

ECONOMIC IMPACT AND CALL TO ACTION

Many of the features and benefits of 3D LiDAR highlighted above have a direct economic impact in terms of saving costs related to the physical security operations of critical infrastructure and improving overall effectiveness:

- **Lower Total Cost of Ownership (TCO) by reducing the total number of devices needed to cover the area to be secured**
- **Reduced infrastructure, installation, and maintenance costs**
- **Savings on guard services by reducing the number of false alarms by several orders of magnitude, avoiding alarm fatigue, improving response efficiency, and never missing a real threat**
- **Reduced pilferage and theft**
- **Faster and more accurate investigations**
- **Avoid fines by gaining the required risk reduction to meet regulatory/compliance requirements**

Additionally, urgency is required to upgrade legacy technologies fast becoming obsolete with state-of-the-art solutions to guarantee the effective protection of critical infrastructure.

LIDAR SERVICEABLE ADDRESSABLE MARKET (SAM) AND REVENUE OPPORTUNITY FOR PHYSICAL SECURITY MARKETS

Chart 1 through Chart 3 show the LiDAR market outlook for various physical security segments. The global installed base of LiDAR sensors across key physical security segments will exceed 3 million by 2030, with water infrastructure assets as the largest segment. The yearly revenue opportunity will exceed US$6 billion in 2030.

Chart 1: Physical Security LiDAR Sensors, Critical Infrastructure SAM by Region World Markets: 2024 to 2030

(Source: ABI Research)

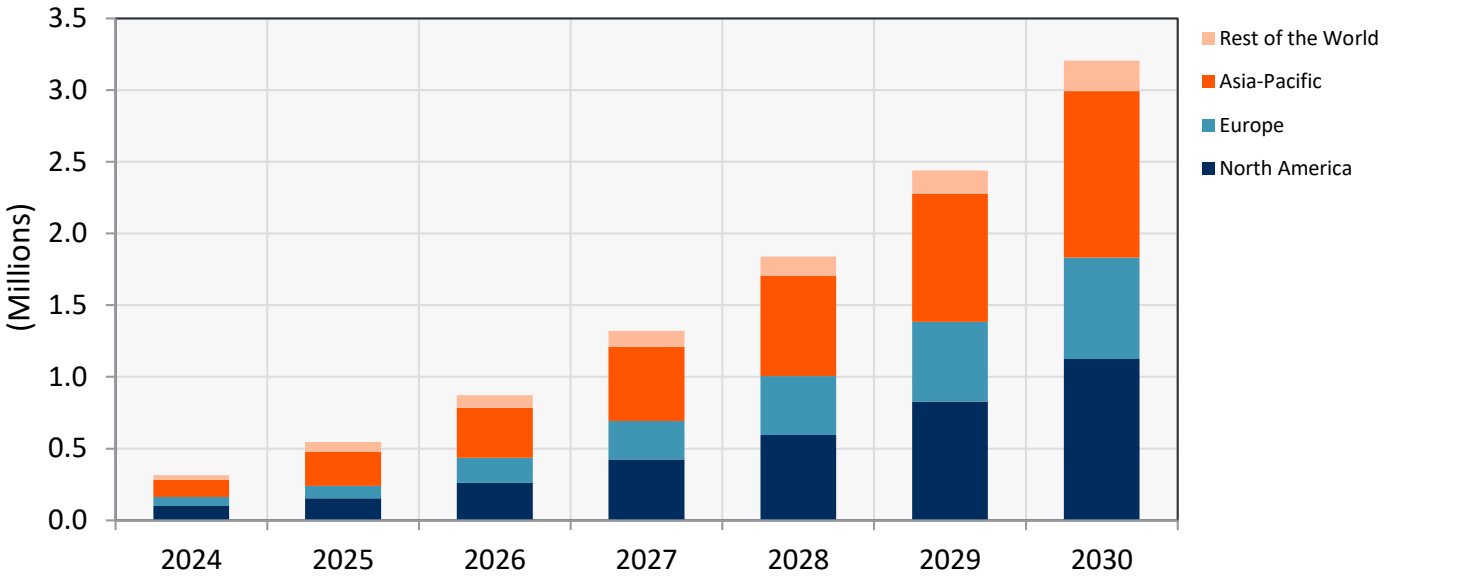


Chart 2: Physical Security LiDAR Sensors, Critical Infrastructure SAM by Segment World Markets: 2024 to 2030

(Source: ABI Research)

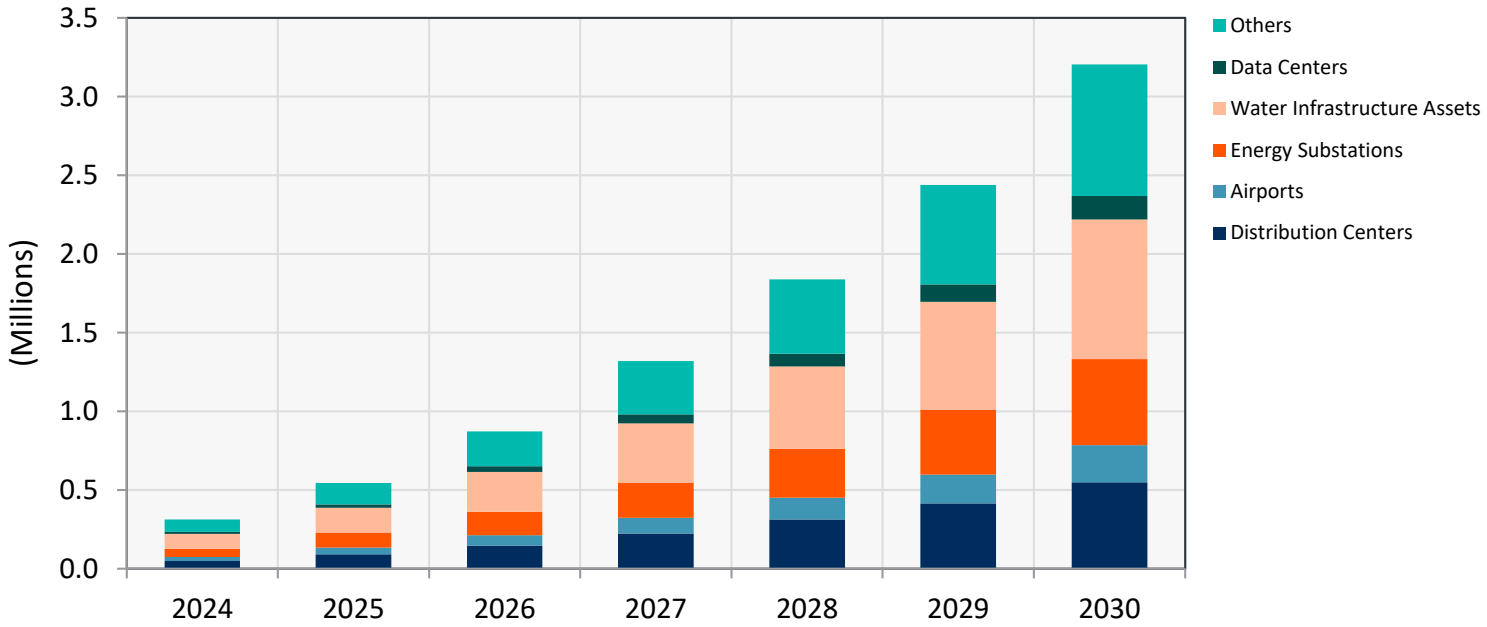
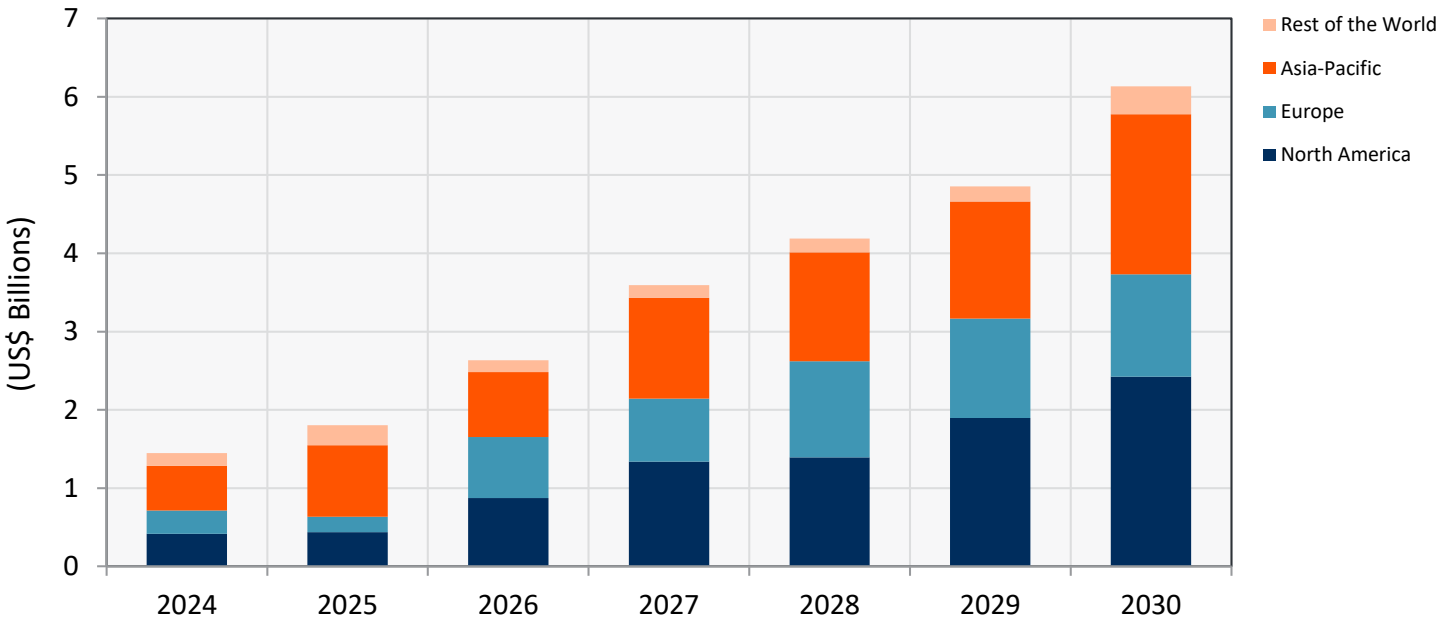


Chart 3: Physical Security LiDAR Sensors, Yearly Critical Infrastructure Revenue SAM by Region World Markets: 2024 to 2030

(Source: ABI Research)



PHYSICAL SECURITY TECHNOLOGIES COMPARISON: CAMERA VERSUS RADAR VERSUS LIDAR

KEY CHARACTERISTICS AND BENEFITS OF LIDAR TECHNOLOGY

As it relates to physical security, LiDAR sensors offer a wide range of unique capabilities and associated benefits, which together propel LiDAR as the technology of choice for Perimeter Intrusion Detection (PID):

- **3D 360° Awareness and Perception:** LiDAR's 3D 360° spatial awareness offers insight into the depth of objects in the viewing field, enabling advanced insight into what is happening in the scene (i.e., precise classification with no blind spots).
- **Long Range Detection:** More than 100 meters (m) of coverage per sensor, facilitating blanket coverage with fewer sensors (5X the coverage area of a single camera), reducing infrastructure costs (e.g., cabling, networking, energy).
- **High Resolution and Accuracy:** Greater than 95% object detection and classification accuracy alleviates alarm fatigue. Level of granularity allows reliably detecting extremely small objects such as golf balls, pens, Universal Serial Bus (USB) sticks, boxes, or packages thrown over fences with a very low rate of false alerts.
- **Robust Performance in Harsh Environments:** Obscurant penetration in darkness, low light, rain, fog, smoke, and lightning.

- **Mesh Architecture Enabling Continuous Tracking:** Seamless and ubiquitous identification and complete trajectory and speed tracking across entire sites virtually for an unlimited range with sensor fusion technology enabling continuous object tracking.
- **Privacy Preservation:** Inherent inability to recognize persons or obtain Personal Identifiable Information (PII).
- **Ease of Deployment:** Simple setup, configuration, and maintenance.

TECHNOLOGY COMPARISON

Table 1 summarizes and compares the characteristics of LiDAR, camera, and radar sensors for physical security. While LiDAR excels in most characteristics, it can be successfully deployed in conjunction with other technologies, either in 2-stage detection configurations or for adding redundancy / facial recognition capabilities, complementing existing investments (integration with VMS Video Management System, augmenting of camera-based PID systems).

Table 1: Summary and Comparison of the Characteristics of LiDAR, Camera, and Radar Sensors for Physical Security

(Source: ABI Research)

CHARACTERISTIC	LIDAR	OPTICAL IMAGING/ PTZ CAMERAS	RADAR
False Alarm Rates	Very Low	High	Medium/High
3D Perception	Yes	No (2D)	No (1D)
Object Qualification Accuracy	High	Medium	Low
Location Accuracy	<3 Centimeters	1 meter	1-3 meter
Scanning Angular Resolution	High	Medium	Low
Coverage per Sensor	High	Medium	Very High
Field of View (Angle)	High - 360°	Medium	Low/Medium
Robustness to Bad Weather and Lighting	High	Low	Very High
Privacy Protection	Yes	No	Yes
Mesh Capabilities for Continuous Tracking	Yes	No	No
Cost of Ownership at Scale	Low/Medium	High	High

KEY CRITICAL INFRASTRUCTURE MARKETS: OPPORTUNITIES AND CHALLENGES

ENERGY SUBSTATIONS

Many energy substations are in remote or rural locations and are usually unmanned, requiring remote monitoring and control technologies. Remotely controlled and autonomously operating High Voltage (HV)/Medium Voltage (MV) and MV/Low Voltage (LV) substations will be instrumental in managing increasingly complex energy grids in the form of Distributed Energy Resources (DER). With the value of both energy and water increasing fast, they are becoming critical assets, and as the weakest link in the energy grid, they require advanced physical security protection. With energy generation becoming more distributed, substations will gain in importance.

The number of power substations in the United States amounts to more than 50,000, compared to less than 10,000 power plants. China has around 150,000 distribution substations. The global number of transmission substations down to 110/115 Kilovolts (kV) amounts to more than 60,000, while the number of distribution substations operating at voltages below 115 kV exceeds 200,000. The number of malicious cyber and physical sabotage attacks on these assets has been increasing.

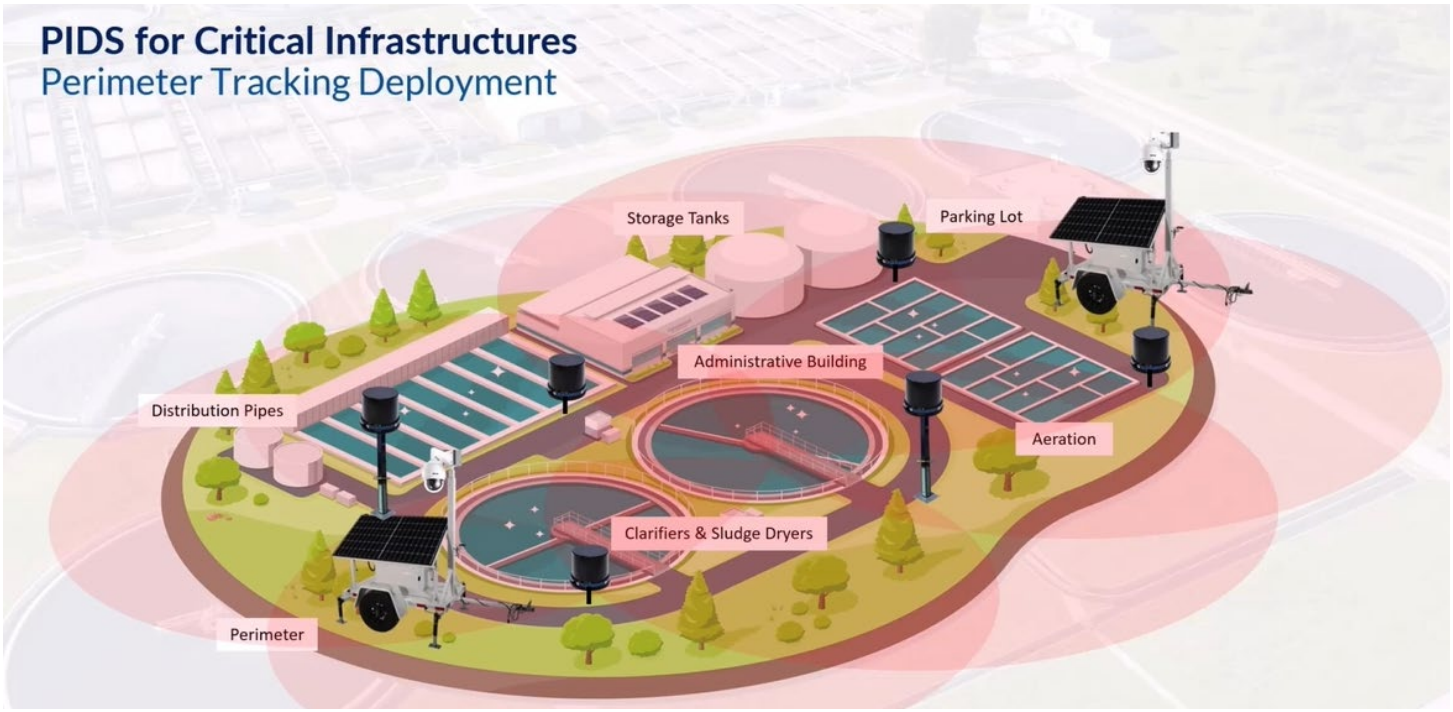
WATER UTILITIES

Like energy substations, water utilities sites are often in remote or rural locations and are usually unmanned, requiring remote monitoring and control technologies. With water fast becoming a premium resource, physical security protection of critical infrastructure to collect and distribute water is becoming more important as they are vulnerable to contamination with deadly agents. Water utilities are designed to capture, store, recycle, purify, and distribute drinking water. Assets include storage facilities such as reservoirs, water tanks, or water towers; water treatment and drainage facilities; and water collection points, pumping stations, and distribution infrastructure such as tunnels and aqueducts. These assets can either be combined in single locations or distributed as separate infrastructure.

In the United Kingdom alone, around 6,000 service reservoirs and 1,433 water treatment works are owned, operated, and maintained by water utilities. According to the Cybersecurity and Infrastructure Security Agency (CISA), there are approximately 153,000 Public Water Systems (PWSs) and more than 16,000 publicly owned wastewater treatment systems in the United States.

Figure 1: Water Infrastructure Monitoring

(Source: Quanergy Water Utilities Webinar)



DATA CENTERS

Data centers are a fast-growing critical infrastructure category, driven by strong expansion of cloud-based data, analytics, Software-as-a-Service, and Artificial Intelligence (AI) applications and capabilities. The global number of data centers currently exceeds 9,000, growing fast at a rate of more than 5%. Data centers are increasingly considered to be mission-critical assets, enabling a very wide range of consumer, commercial, and industrial operations, and services. Hyperscalers like Google and Amazon Web Services (AWS) put forth great effort in guaranteeing uninterrupted operation of data centers through state-of-the-art smart energy supply systems, including on-site microgrids and battery storage, advanced cybersecurity measures, and physical security solutions for PID and server rack monitoring. Moreover, data centers are becoming more distributed, located closer to the Operational Technologies (OT) systems such as factory automation they enable through lower latency access to their services. These smaller, more dispersed data centers are more prone to physical security risks and require reliable technology solutions.

DISTRIBUTION CENTERS AND WAREHOUSES

Centralized distribution centers and warehouses are increasingly complemented with Micro-Fulfillment Centers (MFCs) and shared warehouse services to address scarce resources and be located closer to end users from a last-mile, near real-time delivery perspective. This more dispersed nature of distribution centers makes them more vulnerable to physical security threats such as theft.

According to ABI Research, the total number of store-attached and standalone MFCs will grow from 526 in 2023 to 5,758 in 2030, of which 46% will be located in North America. The overall total number of warehouses will grow from 160,000 in 2023 to 222,000 in 2030, of which 35,000 will be located in North America.

Globally, in 2030, e-commerce fulfillment centers represent a share of 21%, distribution centers a share of 55%, and storage warehouses a share of 24%. The global dry storage warehousing space will reach 11 billion square feet in 2023, 16% of which will be in North America. The average dry storage space per warehouse will amount to 4,633 square meters in 2030.

AIRPORTS

Airports are highly concentrated "microcities"—centers of economic activity that are heavily secured, as they have been targets of various forms of terrorism in the past. The global number of large and/or international airports can be estimated at around 1,400. However, smaller airports need similar levels of physical security protection.

Physical security applies to both entering terminals and access to airplanes and runways. More generally, aviation is prone to various forms of security risks due to its highly vulnerable nature. Consequently, aviation-grade safety and security have been taken to the highest possible level. Next to physical security, sensor technologies like LiDAR are also mainly deployed for people flow and queue management inside airport terminals, mainly in larger airports.

OTHER CRITICAL INFRASTRUCTURE SEGMENTS

CISA, part of the U.S. Department of Homeland Security (DHS), defines 16 critical infrastructure sectors, including:

- **Military Sites and Their Supply Chains:** Sites like army barracks require the highest possible protection against intrusion attempts, with alarm fatigue caused by many false alarms constituting a real problem.
- **Road Infrastructure and Transportation Systems:** This segment is faced with complex environments such as tunnels and challenging terrain/lighting conditions making reliable monitoring and protection of road assets problematic.
- **Chemical Plants and Critical Manufacturing Infrastructure**
- **Communication Infrastructure**
- **Government and Healthcare Facilities**

LIDAR CASE STUDIES FOR PHYSICAL SECURITY SEGMENTS

LiDAR sensor technology can enable most mission-critical security use cases, including PID, server rack and cabinet security, mobile security towers, mantrap/vestibule access controls, and rooftop security.

ENERGY PLANT/SUBSTATION PERIMETER INTRUSION DETECTION—HARSH ENVIRONMENTS

Next to the more general issue of the low accuracy of legacy security/PID systems and the associated false alarms, energy substations are forced to cope with a lot of obstacles and occlusions, adverse weather conditions, and harsh terrain. This is where LiDAR sensors can offer more reliable security operations that consistently protect sites from intrusion. Moreover, unlike radar, LiDAR is immune from interference from metallic structures, abundant in energy plants.

DATA CENTER PERIMETER INTRUSION DETECTION—ALARM FATIGUE REDUCTION

Alarm fatigue is one of the main issues data centers and cloud services providers are facing. Legacy PID security systems generate a lot of costly false alarms, up to hundreds of thousands during just a few months, risking masking real threats. LiDAR technology has exhaustively been tested and proven effective in successfully and systematically detecting a wide range of intrusion attempts, including people jumping over fences, tunnels dug below lakes, and lowering buckets from drones to block sensors with a very low false alarm rate. LiDAR sensors can be deployed over very diverse terrain, with diverse elevations and slopes. LiDAR can significantly reduce the number and cost of data center guard services. Moreover, data centers make extensive use of cameras to track the movement and access of people in and around their cages and server racks. Given their limited Field of View (FOV), data centers need to deploy a very large number of cameras, resulting in very high costs. A single LiDAR sensor can replace 5 to 10 cameras, dramatically reducing these costs, while avoiding dangerous blind spots.

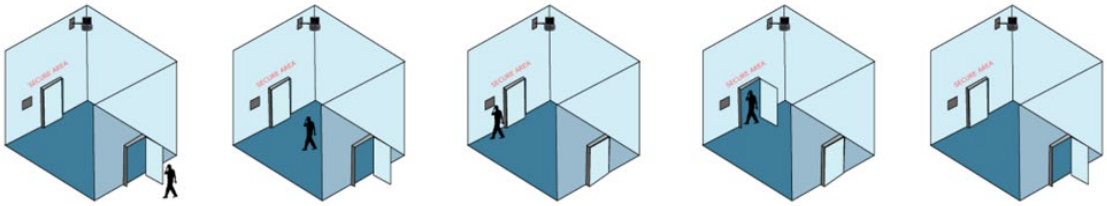
DISTRIBUTION CENTERS—PERIMETER INTRUSION DETECTION/LOSS PREVENTION

Many delivery solution providers and logistics companies experience a high rate of lost parcels at their distribution centers. Issues include warehouse employees throwing packages over the fence and the detection of intruders in large open areas. LiDAR technology makes it possible to create a curtain across the entire fence line and detect even the smallest of objects thrown over the fence, as well as the continuous tracking of people in open environments. Insights from LiDAR sensors can be integrated with existing video management systems. Overall results range from a 10-fold reduction in package loss and theft to the almost entire elimination of false alarms and missing very few intrusions in open areas.

MANTRAP PORTALS AND DOORS

Tailgating represents a major physical security risk at airports, and other critical infrastructure assets like data centers. Unauthorized persons can breach access control

security solutions by closely following an authorized person through mantraps, portals, or vestibules that separate secure and unsecure areas. LiDAR sensors offer superior people counting capabilities in terms of reliability and accuracy compared to cameras, eliminating any remaining intrusion risk, keeping secure doors locked when two or more people are counted, and only letting the next person in when the mantrap has been validated to be empty. Typically, it requires two LiDAR sensors to fully secure mantraps.



MOBILE SURVEILLANCE UNITS—PERIMETER INTRUSION DETECTION OF REMOTE SITES

The physical security of remote sites represents specific challenges in terms of the lack of infrastructure and cabling, the reliable surveillance of very large open spaces, adverse light and weather conditions, and the requirement of remote monitoring. A LiDAR-based mobile/portable surveillance solution addresses these key problems. It offers high accuracy and a low rate of false alarms needed for remote monitoring and can be deployed easily in remote areas.

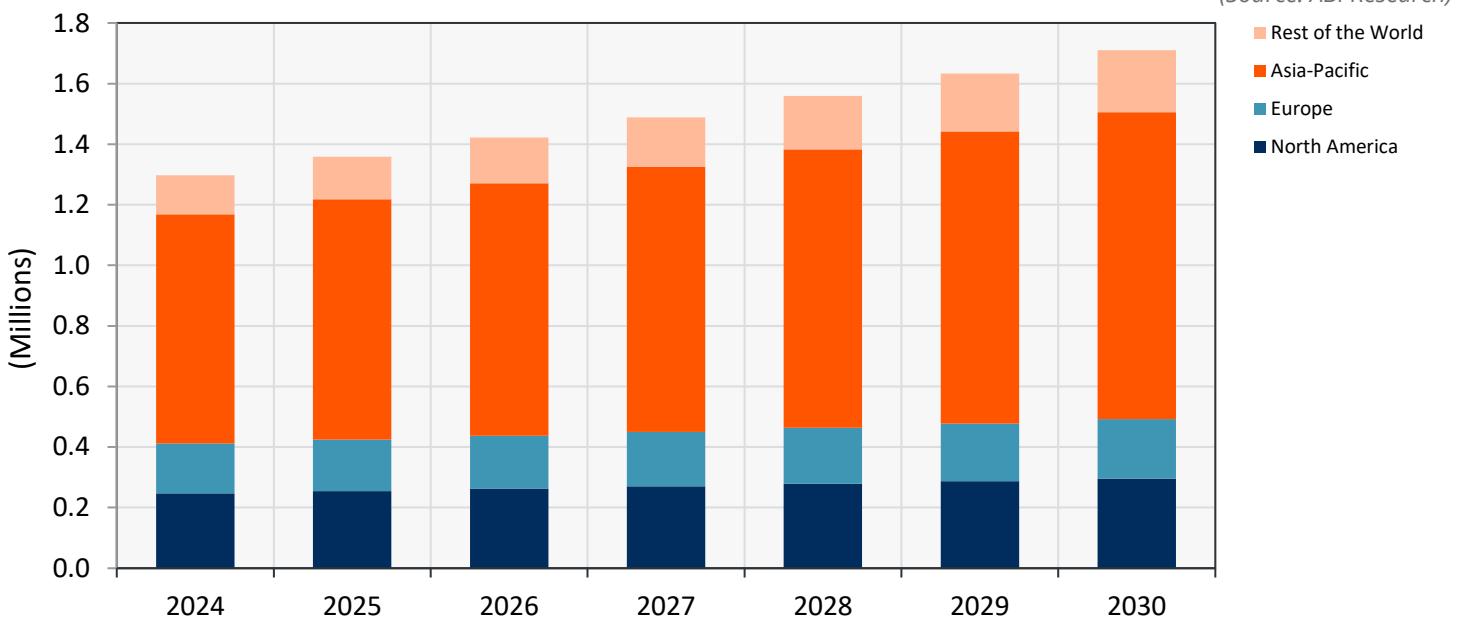
PHYSICAL SECURITY LIDAR MARKET SIZING AND FORECASTS—SAM

The SAM outlook for key physical security segments is provided below.

ENERGY SUBSTATIONS

Chart 4: LiDAR Sensor SAM in Energy Substations by Region World Markets: 2024 to 2030

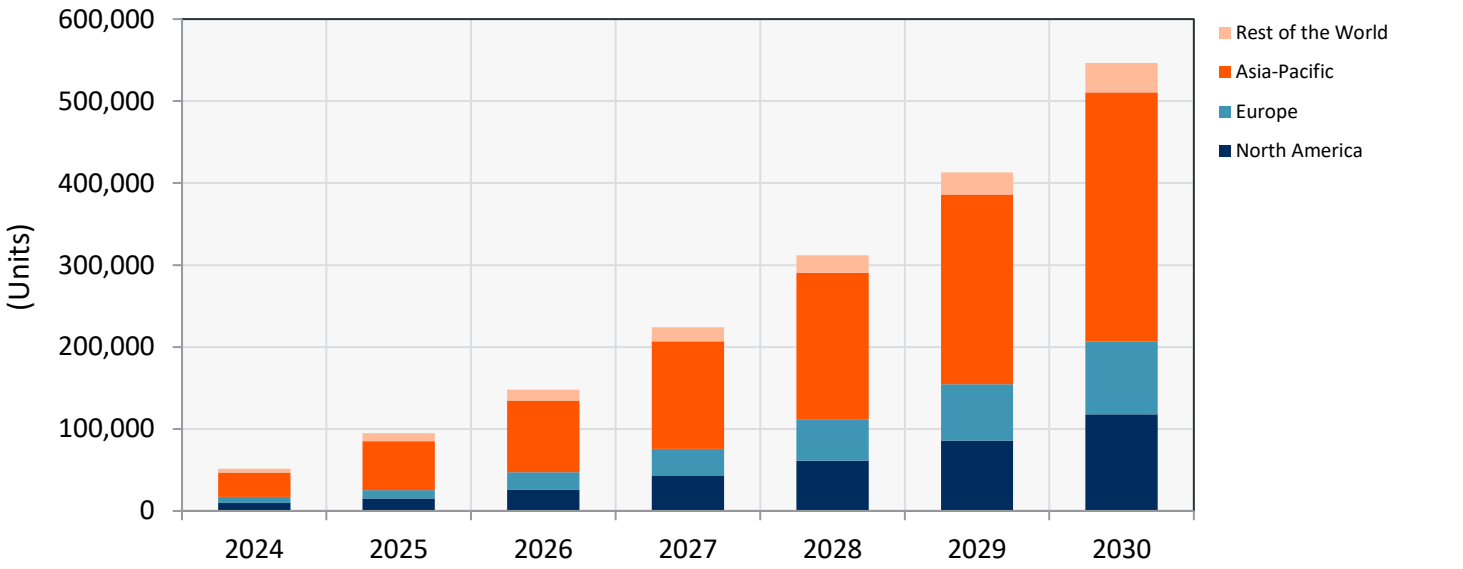
(Source: ABI Research)



WATER INFRASTRUCTURE ASSETS

Chart 5: LiDAR Sensor SAM in Water Infrastructure Assets by Region World Markets: 2024 to 2030

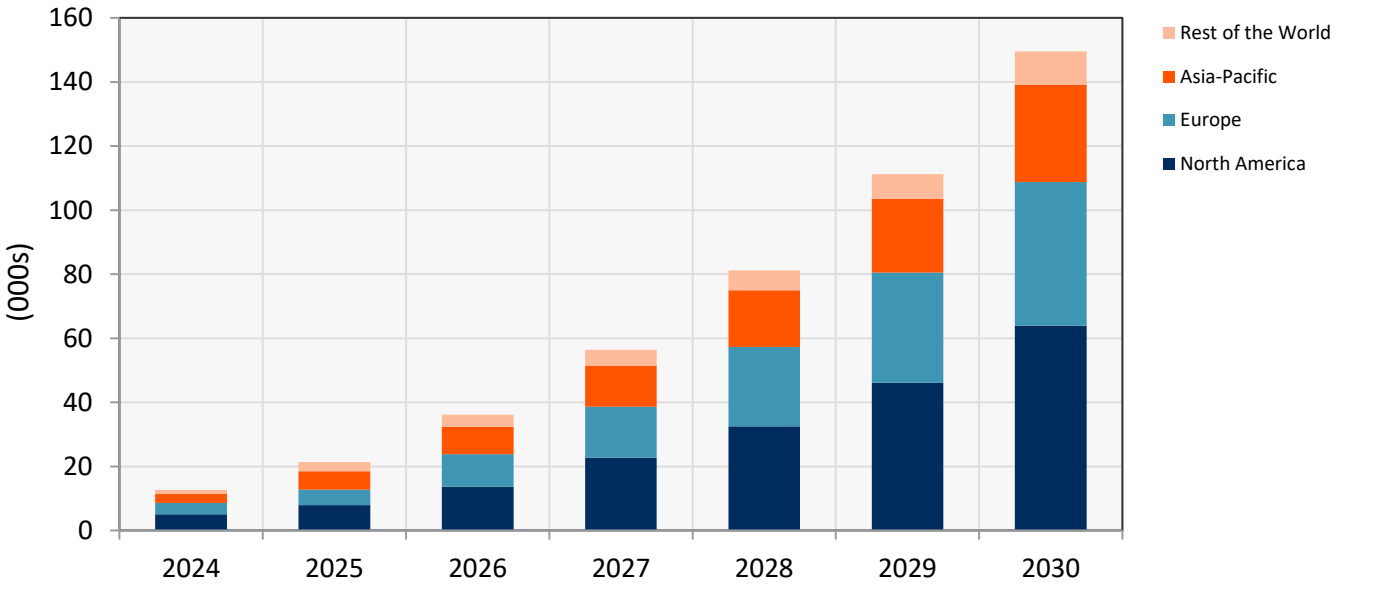
(Source: ABI Research)



DATA CENTERS

Chart 6: LiDAR Sensor SAM in Data Centers by Region World Markets: 2024 to 2030

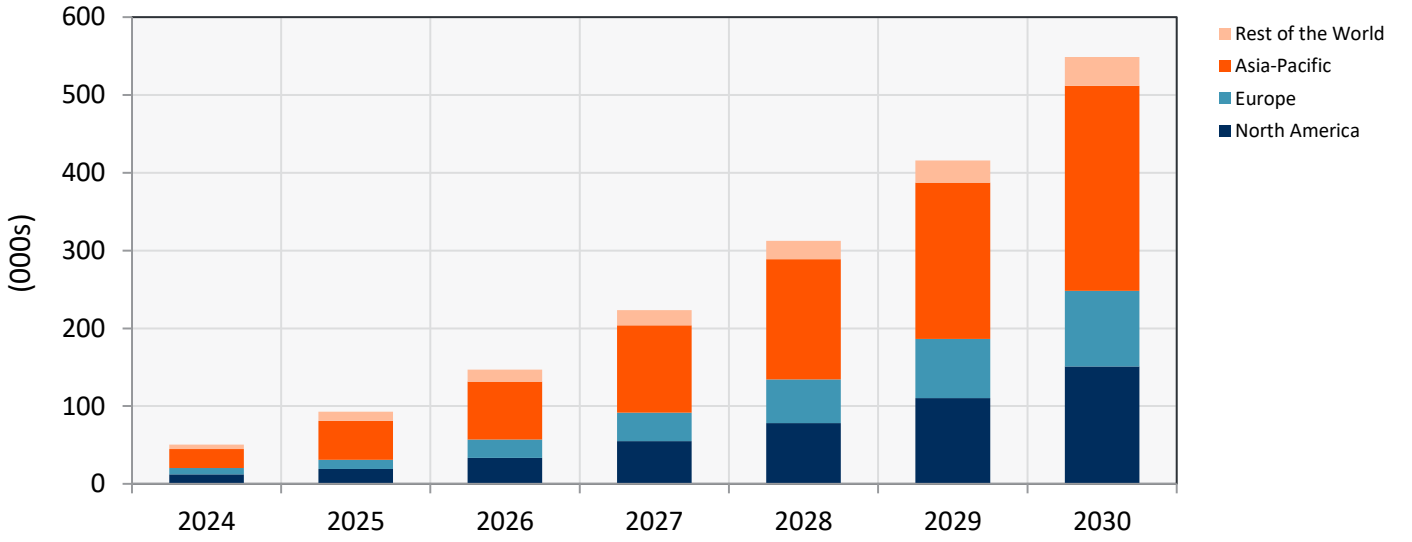
(Source: ABI Research)



DISTRIBUTION CENTERS

Chart 7: LiDAR Sensor SAM in Distribution Centers by Region World Markets: 2024 to 2030

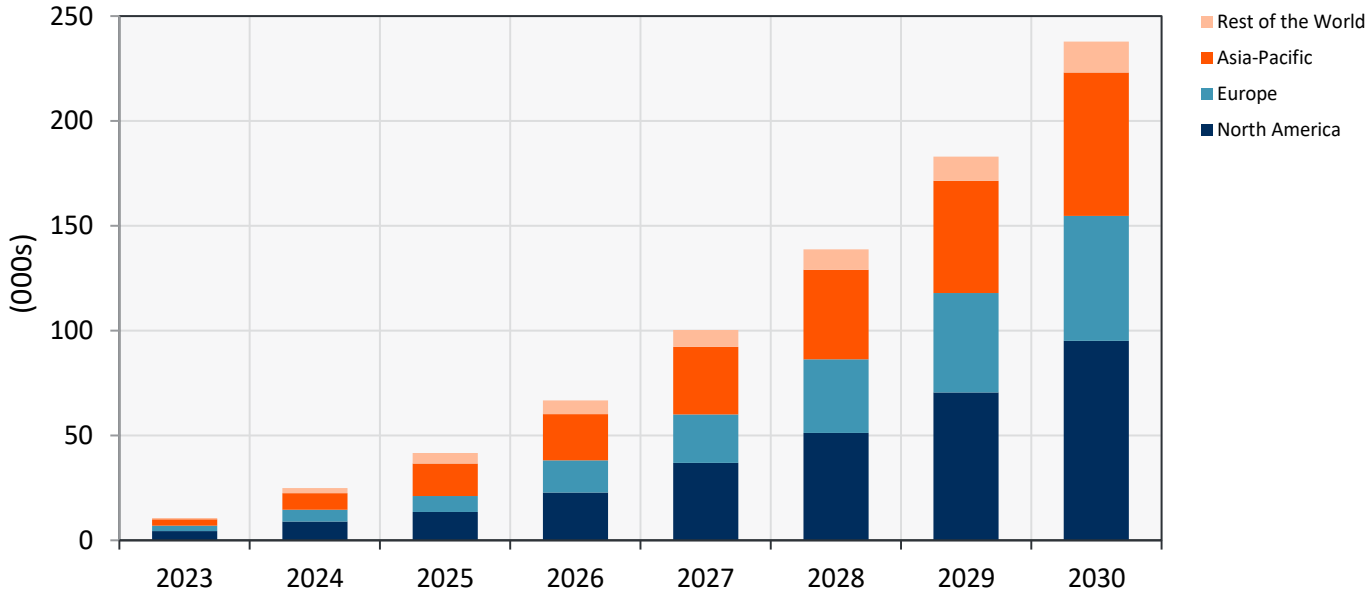
(Source: ABI Research)



AIRPORTS

Chart 8: LiDAR Sensor SAM in Airports by Region World Markets: 2024 to 2030

(Source: ABI Research)



QUANERGY LIDAR SOLUTIONS FOR PHYSICAL SECURITY

California-based Quanergy develops LiDAR solutions for the critical infrastructure, smart spaces, and smart cities. Key products include:

- **Q-Track®:** Integrated hardware and software solution combining Quanergy's long-range 3D LiDAR sensors with AI-enabled perception software providing hyper-accurate 3D situational awareness and the simultaneous detection, classification, and tracking of more than 1,000 individuals/objects across large areas per server. It is also offered as a Security-as-a-Service (SaaS) subscription avoiding Capital Expenditure (CAPEX) in favor of Operational Expenditure (OPEX). It includes 3D sensors, a perception software license, support, maintenance, upgrades, and a warranty.
- **M1 Edge PoE:** 2D LiDAR sensor with a range of up to 200 Milliseconds (ms) integrated with QORTEX Aware object detection software aimed at security applications such as rooftop security, fence protection, server rack protection, asset protection at museums/art galleries, etc.

Quanergy's LiDAR solutions offer a wide range of unique benefits:

- Seamless integration with over 40 existing security systems, including Video Management Systems (VMSs), cameras, access control solutions, Physical Security Information Management (PSIM) software, and analytics solutions.
- 360° 3D coverage and 140 m range (diameter) per sensor.
- >98% accurate detection and counting, and >95% accurate tracking and classification.
- Continuous tracking and mesh architecture.
- Best-in-class horizontal angular resolution.
- Simultaneous tracking of 1,000+ objects/server
- PoE+ Enables Plug and Play Deployment
- NDAA, BAA, TAA, GDPR complaint. No PII recorded.

QUANERGY RESOURCES

More information about Quanergy's solutions for physical security is available. Please also watch the webinar hosted with San Jose Water, one of the largest and most technically sophisticated urban water systems in the United States.

CONCLUSIONS

ABI Research believes that 3D LiDAR solutions will have a transformational impact on the physical security market, redefining how to protect vulnerable critical infrastructure. The unique characteristics of LiDAR in terms of detection accuracy and reliability, range and FOV, continuous tracking, ease of deployment, and privacy preservation make it the technology of choice for next-generation physical security solutions to protect a wide range of mission-critical assets in the utility, data center, airport, and other critical infrastructure segments.

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