Exploration of **panoramic surveillance**

BOSCH

Comparing single-lens panoramic cameras with multi-lens, fixed and PTZ cameras

Abstract

This white paper compares single-lens panoramic cameras with multi-lens panoramic cameras, fixed cameras and PTZ cameras. It explains the differences from a technical perspective and how different cameras can complement each other. This white paper also provides insight on which applications can benefit most from panoramic cameras. Importantly, it includes in-depth technical knowledge and user advice on how to choose the right camera for a video surveillance case.

Securing public areas with video surveillance can be challenging. Specifically, blind spots cause problems when tracking people passing through the area. Whether it is an airport, a bank building or a retail outlet, there are lots of places where it is important to monitor people from the moment they enter the building and follow them as they move around. All of their movements may be crucial in terms of monitoring behavior or forensic search. Even though today's conventional IP cameras usually deliver perfect images of what they "see", they simply cannot see everything – there will always be blind spots. However, a panoramic camera can eliminate blind spots that would otherwise impact the effectiveness of video surveillance. But how do panoramic cameras work and in what kind of applications can they be beneficial?

Panoramic surveillance

Following the transition from analog to IP video surveillance over recent years, multi-megapixel (MMP) cameras are now grabbing all the attention. While the dramatic increase in resolution benefits any surveillance application, it has also spurred development of high resolution panoramic cameras. Panoramic cameras usually come in two different types: a 360° or a 180° field of view. The extraordinary 360° field of view of these cameras, coupled with exceptionally high resolution sensors of 12 megapixels and even beyond, results in detailed overview images in one single view. Usually installed in a ceiling, a 360° camera covers the entire area below the camera, providing a full surround view without any blind spots. A 180° panoramic camera provides full situational awareness when installed on a wall, e.g. in corridors or reception areas. Panoramic cameras start to prove themselves as a critical component when building a video surveillance system that needs to meet the highest security standards as their ability to avoid blind spots enables operators to minimize the risk of missing important information.

Two panoramic camera designs: multi-lens panoramic cameras and single-lens panoramic cameras

(1) Multi-lens panoramic cameras generally have three or four lenses/sensors. The camera stitches together the separate video streams from each sensor to form a single image.
(2) Single-lens panoramic cameras use an extremely wide angle lens of 180° or 360°.

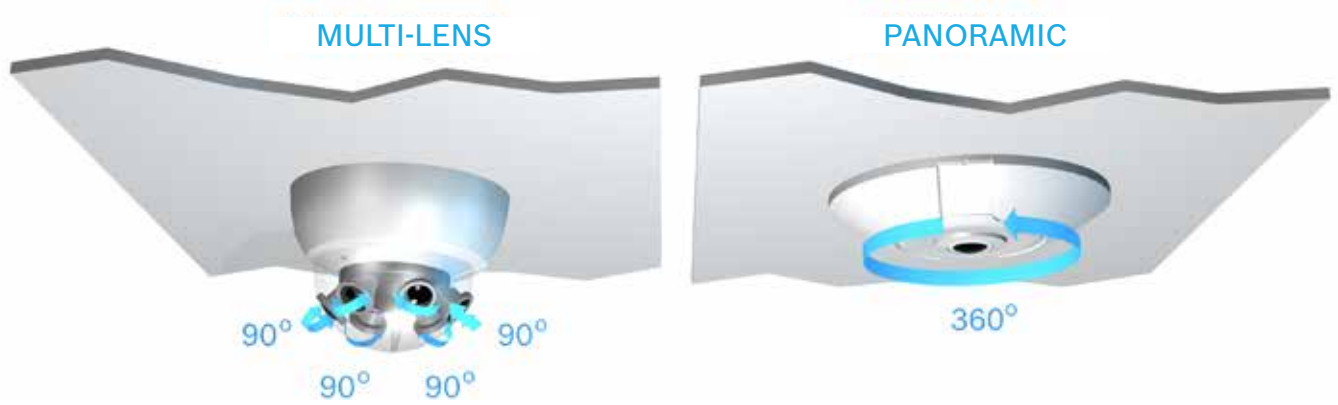

Fig. 1: Multi-lens panoramic camera versus single-lens panoramic camera

A multi-lens camera provides four images from 90° lenses. The images are rectangular in shape and are not optically distorted. However, to create full situational awareness the images need to be stitched together using specific software.

A single-lens panoramic camera uses a fisheye lens that creates a hemispherical image of the full region located below the lens. These lenses form a circular field that ranges 180° horizontally and 180° vertically. Optical distortion correction technology is needed to create useful images, this is known as ‘dewarping’ and will be covered in greater detail in the section “Dewarping”. Single-lens panoramic cameras are generally available in two versions: 180° and 360°. The difference is in the size of the projected image circle. With a 360° camera, the sensor captures the full hemispheric region. The circular image fits the size of the sensor and has a 180° field of view horizontally and 180° vertically. With a 180° camera, the circular image fits within the vertical field of view of the sensor, but not within the horizontal field of view. The camera therefore has a 180° field of view horizontally, but less than 180° vertically.

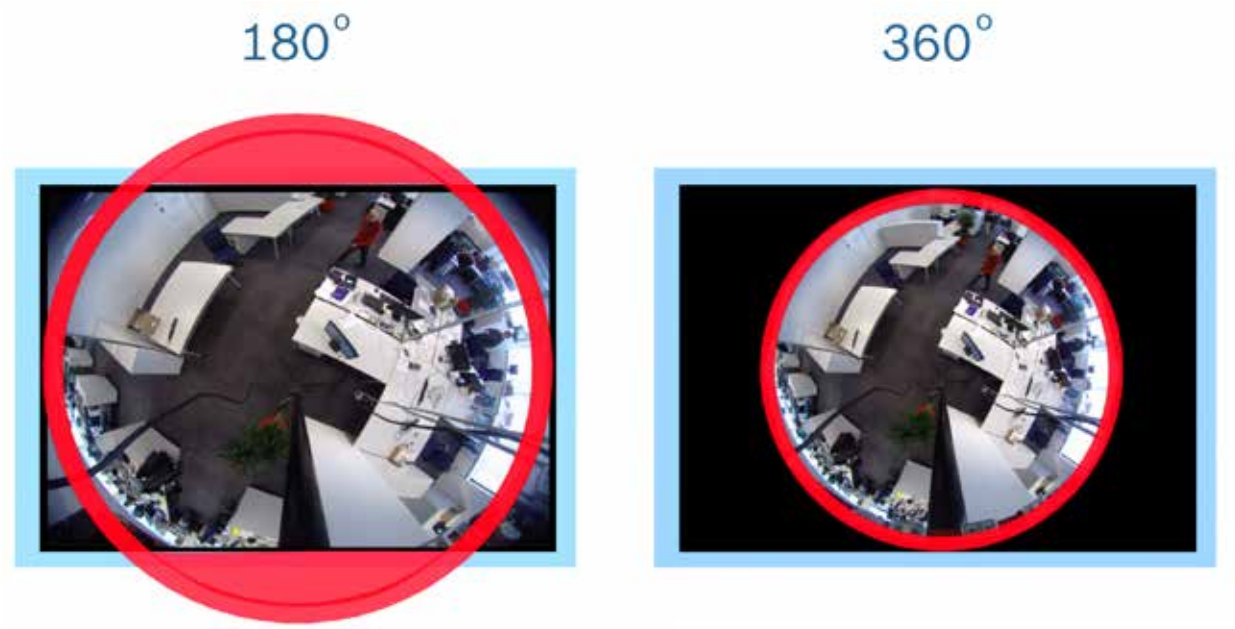

Fig. 2: Optical projection of a 180° and 360° lens

This means that there are two techniques available to gain full situational awareness over 360°, using a single camera. Each one has its own benefits analysis as the comparison below shows:

	Multi-lens camera	Single-lens panoramic camera
Size and Weight	Weight around 0.9 to 1.8kg Height around 165 mm	Weight around 0.2 to 1.1kg Height around 55 mm
Cost	Up to 3x of single-lens panoramic camera	More cost effective than multi-lens panoramic cameras
Resolution	Effectively using all pixels	Not using full sensor size and available pixels. This is caused by circular lens projection
Image Performance	Detail level equal over the image	Concentrate detail in the center of the image for better view
Special VSDK	Needed	Not needed
Power	Need more power for multi lenses	No increased power needed

Fig. 3: Comparison between multi-lens panoramic camera and single-lens panoramic camera

The many advantages offered by single-lens panoramic cameras have led to their increasing popularity in the security market. This white paper will continue with the focus on single-lens panoramic cameras.

Panoramic versus fixed cameras

Panoramic cameras are used to gain full situational awareness with a single camera. Fixed cameras are a great complement to camera systems when identification and details in a more restricted scene are needed on short and long distances – for instance, when monitoring a local grocery store or overseeing an entire queuing area at an airport. However, a panoramic camera can be used to provide a complete overview of a certain area.

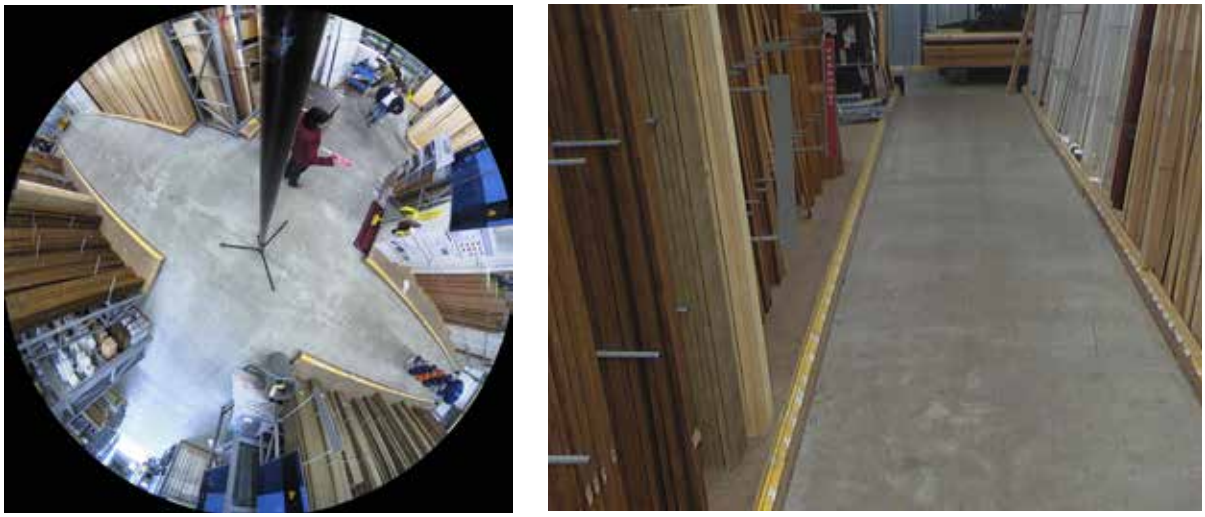

Fig. 4: 360° surround view vs. conventional fixed camera view

	Fixed camera	Single-lens panoramic camera
Field of view	Limited (usually up to 120°)	Extremely wide (up to 360°)
Coverage	Only in the direction the camera points at	360-degree overview
Resolution	Use of full resolution availability More useful pixels per image	Unable to use all pixels effectively
Image distortion	No or limited distortion	Distortion correction needed (dewarping)
Video Content Analytics	Tracking of objects within the field of view	Tracking of objects over 360-degree

Fig. 5: Comparison between fixed and single-lens panoramic camera

Panoramic versus moving camera (PTZ)

A PTZ camera provides identification possibilities on short and long distances thanks to its optical zoom, which has a larger range than the panoramic camera. PTZ cameras can display and record only one part of the scene and are sometimes pointing in the wrong direction when an event occurs. This is where panoramic cameras can complement PTZ cameras by monitoring and recording all events and activities in the full area simultaneously. This means that operators have full-area access to both live and recorded images. The panoramic camera monitors, analyses and continuously records everything. What's more, panoramic cameras can effectively pan, tilt and zoom into a specific region without losing sight of other regions of interest. However, a panoramic camera can zoom in only digitally and is therefore not very suitable for identification as resolution drops due to loss of pixel density.

To summarize, panoramic cameras and PTZ cameras can complement each other by eliminating each other's weaknesses.

Fig. 6: Conventional PTZ camera view versus 360° surround view

	PTZ camera	Panoramic camera
Coverage	Record and monitor only one region at a time	Always full surround
Size	Weight around 1.5 kg to 2.6 kg Height around 155 mm	Weight around 0.2 kg to 1.1 kg Height around 55 mm
Aesthetics	Obtrusive	Discrete
Power	Often needs PoE+	PoE
Zoom	Optical (up to 30x)	Digital (factor depends on resolution)
Identification	Short and long distances	Limited
VCA	Limited to current field of view Tracking over 360°	In full surround view tracking over 360°

Fig.7: Comparison between PTZ camera and panoramic camera

A typical scenario is to use a 360° camera to monitor the entire area and a PTZ camera to zoom in on a certain event within that area.

Image Performance

The image performance or quality of a panoramic camera depends on the sensor and the image processing algorithms applied. When assessing image performance, users typically look at four areas: resolution, dynamic range, sensitivity and bitrate.

Resolution

Resolution is the number of pixels that can be displayed. If the number of pixels on the sensor is low, the image resolution will be low, and details will not be visible. Low resolution results in either pixilated or blurred images, especially in places where panoramic lens distortion needs to be heavily corrected and the correction algorithms need to expand images.

A camera containing a sensor with more pixels will require significantly greater computing power.

The introduction of multi-megapixel security cameras has improved image quality in general and the quality of panoramic cameras in particular. The sensors and lenses currently available in the market enable security companies to promise premium performance using panoramic cameras.

The resolution of a panoramic camera is not as straightforward as conventional security cameras. A panoramic camera using a 12 megapixel (MP) sensor will not provide full 12MP resolution. The optical circle of the lens is smaller than the active image area of the sensor and therefore does not cover all active pixels. The effective resolution of the image is the amount of pixels that will fit within the optical circle. As an example, take a 12MP sensor with 4000x3000 pixels and measuring 6.20x4.65 mm. The 360° optical circle of the lens has a diameter of 4.1 mm. This would result in square with a resolution of 7.0MP. So when selecting a panoramic camera it is important to know whether it will really provide the advertised resolution or whether this is just the sensor's resolution.

Dynamic range and sensitivity

Besides capturing details, the sensor is also responsible for the dynamic range and low light sensitivity of the camera. The usability of a panoramic image is highly dependent on the dynamic range of the sensor (i.e. the strength of its ability to capture detail in both bright and dark areas of the scene – the higher dynamic range the more details the sensor will capture in bright and dark areas). With a panoramic camera, there is a far greater likelihood of bright and dark areas in the field of view. A sensor with a low dynamic range will then not be able to show details in every area of the scene.

Bitrate

All IP networks have a limit to the traffic they can carry, this limit is known as bandwidth. Increasing resolutions means increasing amounts of data and this drives bitrates up. This calls for tools and technologies to help managing video data efficiency. Innovative data compression technologies such as H.265 reduce the amount of data provided by a high resolution camera. Next to compression, the addition of intelligent techniques, such as the Bosch IDNR technique, distinguish relevant and irrelevant information, and enable bitrates to be lowered further.

Intelligent Dynamic Noise Reduction (IDNR)

To reduce bitrates after encoding and further minimize strain on bandwidth and storage requirements, several forms of noise reduction can be applied. “Intelligent Dynamic Noise Reduction” (IDNR) is an innovative technology that uses a combination of two noise reduction techniques: one that is best suited for scenes with motion (spatial noise reduction) and another that is best suited for still scenes (temporal noise reduction). Special algorithms in Bosch cameras determine which scenes have motion, and therefore which noise reduction technique is used. IDNR uses three factors to control spatial and temporal noise reduction:

- Movement analysis
- Light level
- User-set levels where, when an object is detected, the bitrate increases to capture maximum details.

In this way, IDNR reduces bitrates and required storage capacity without affecting video quality.

By combining these processes, bitrate increases when an event occurs and is minimized when there is no motion and thereby lowers the total required bitrate.

Encoder regions

Area-based encoding (encoder regions) can lower bitrates even further. This feature allows the image to be divided into zones of high importance and less compression to show more detail, and those of low importance and therefore high compression and less detail. For example, if the top of the image is always looking at the sky, this area can be marked for high compression. By selecting important, unimportant and normal regions in a scene, and adapting the compression ratios accordingly, a lower average bitrate can be achieved.

Fig. 8a: 360° full image circle / Double panoramic view

Dewarping for distortion-free viewing and recording

The fisheye lens of a panoramic camera produces optically distorted images that are circular in shape. Image correction technology is needed to create an optimized and useful image without distortion, this is known as dewarping. The dewarping algorithm remaps the pixels in the scene to optimize the image and remove distortion. The algorithm can offer various dewarped view mode options such as panorama, double panorama and surround (see Fig. 8). Dewarping can in some cases provide real-time views across multiple streams. The various video viewing modes allow the user to control the 180° or 360° images and guarantee distortion-free video (see images below). It is also possible to define customized Regions of Interests (ROI) by adding presets. This way, dewarping can also help to make video data more manageable.

Fig. 8b: Quad view

Edge versus client-side dewarping

Dewarping video images can be done either by dewarping algorithm on the camera before sending the video data to the Video Management System, this is known as edge dewarping, or on PC via a specific Video Software Development Kit (VSDK), this is called client-side dewarping.

Edge dewarping has some advantages over client-side dewarping:

- **Edge dewarping makes the camera's integration into a system easier.** Most panoramic cameras require a specific VSDK for dewarping, which makes integration into VMS challenging. The VMS will need to support the VSDK, which can result in poor or no integration with 3rd party software. This can, in turn, limit the wide implementation and use of panoramic cameras. Edge dewarping allows the user to see a corrected image directly from the camera without the need of any special integration.

- **Edge dewarping sends undistorted virtual camera images to the VMS.** If the camera architecture allows it, the camera can create multiple virtual cameras, and edge dewarping will help send undistorted virtual camera streams to the VMS. Access rights to the virtual cameras can then be managed by the VMS and so providing different video streams to different users.

- **Lower costs.** Dewarping on the client-side requires a lot of computing power. Edge dewarping is done by the camera rather than using the computer's CPU, which significantly reduces the processing power needed on a PC. Expensive equipment is no longer needed to process the image and all the information that comes with it, thus relieving the pressure on the customers' budget when purchasing panoramic cameras.

- **Lower bitrates.** Edge dewarping enables the user to monitor only those areas that are relevant for the user when there is no need to monitor the entire image circle. Relevant areas can be selected by the user, further lowering bitrates.

Two new panoramic video cameras from Bosch

- FLEXIDOME IP panoramic 7000 MP
- FLEXIDOME IP panoramic 5000 MP

In 2015 Bosch Security Systems launched its first panoramic cameras, the FLEXIDOME IP panoramic 7000 MP and the FLEXIDOME IP panoramic 5000 MP. They offer all the advantages and benefits discussed in the previous pages, and more.

These two new single-lens panoramic cameras are highly competitive alternatives to multi-lens panoramic cameras and cost 50 to 65% less. They also offer the same intelligent data minimization for efficient transmission and storage and are half the size of multi-lens panoramic cameras.

The FLEXIDOME IP panoramic 7000 MP uses a 12MP sensor resulting in effectively 7MP resolution at 30fps The FLEXIDOME IP panoramic 5000 MP uses a 5MP sensor at 15 fps.

The 360° lens on the 5MP sensor results in a 3.2MP effective resolution. Both models include built-in Intelligent Dynamic Noise Reduction (IDNR), which reduces bitrates by up to 50% at the source. This significantly reduces storage costs and network strain without compromising video quality. The FLEXIDOME IP panoramic 5000 MP includes Content Based Imaging Technology (CBIT), which ensures the highest quality of relevant images by tailoring the captured images to the content of the scene. The FLEXIDOME IP panoramic 7000 MP also features CBIT in which Intelligent Auto Exposure automatically adjusts the exposure settings of the camera when the lighting conditions change. This ensures superb front light compensation and incredible backlight compensation. The camera also comes with Bosch's own VCA, Intelligent Video Analysis (IVA), so you are alerted when needed and can trace back important events from hours of video in seconds. You can choose between a 180° lens with effectively 8MP resolution or a 360° lens with effectively 7MP resolution. They both offer edge and client-side dewarping to correct image distortion.

Intelligent Video Analysis

One very attractive feature that makes panoramic surveillance cameras even more useful is Intelligent Video Analysis (IVA). IVA enables detection, tracking, following and analysis of all movements across a 360° scene with no blind spots. All the objects and individuals across a particular area could be fully included in the scene. There is no need to combine the analysis done by multiple fixed cameras, as Fig. 9a. shows. IVA enriches full situational awareness in the camera and ensures easy forensic search and alerts in case of risks. Metadata is recorded to assist the operators in analyzing recorded images. Imagine having days of 360° footage where they need to find a certain person. Forensic search does the job in a couple of seconds.

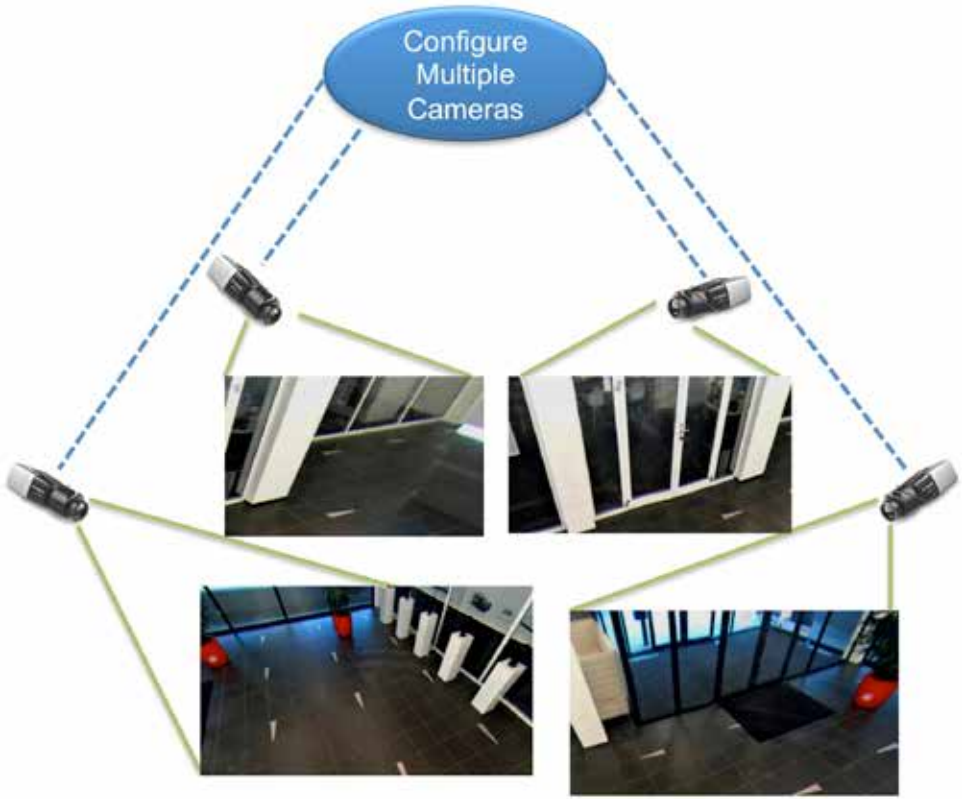

Fig. 9a: IVA configuration multiple cameras

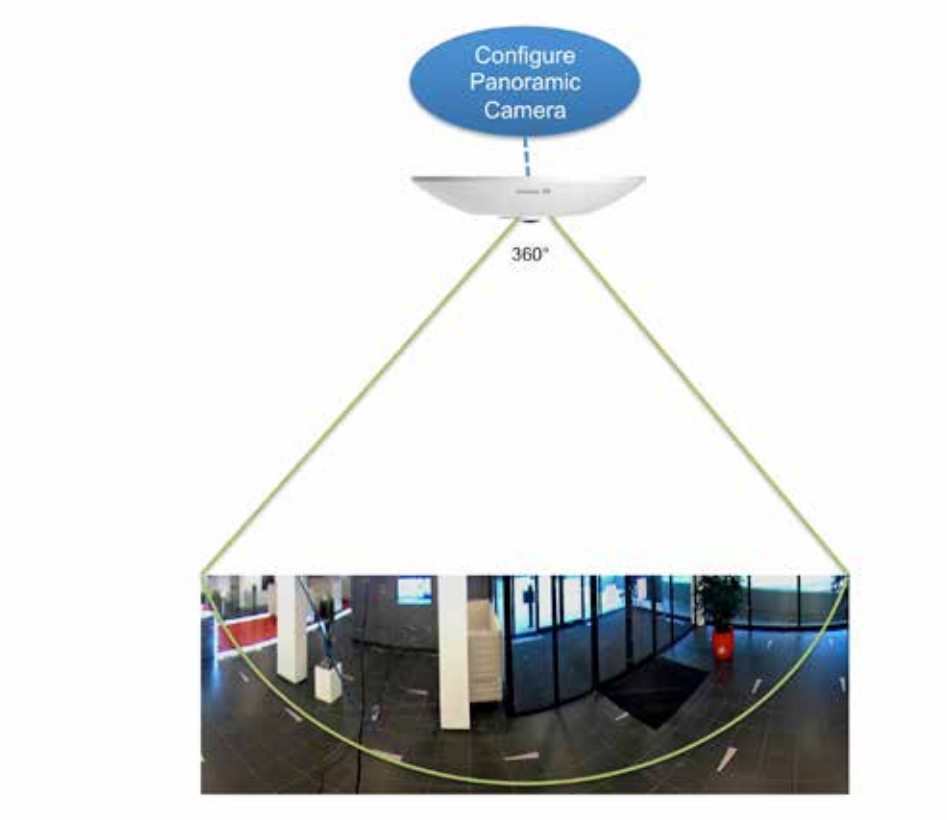

Fig. 9b: IVA configuration panoramic camera

Define your needs with DORI ratings

With its 12MP sensor, the FLEXIDOME IP panoramic 7000 MP belongs to the high-end range of panoramic cameras in the market. It allows you to maintain a full panoramic overview with the possibility to zoom in on certain areas of interest.

If you need more performance from your system, the 7000 range is the right choice. But in cases where the required level of detail is lower, a 5000 range camera with 5MP sensor can be sufficient. Via a simple system called DORI, your needs can be assessed. DORI (Detect, Observe, Recognize, Identify) is a standard system (EN-50132-7) for defining the ability of a camera to distinguish persons or objects within a covered area. This ability is related to the amount of Pixels per meter / foot (PPM / PPF). The images below show the DORI distances for a panoramic camera installed in a 3m / 10ft high ceiling.

DORI at installation height of 3m/10ft
Identification up to 2m/7ft
Recognition up to 4.5m/15ft
Observation up to 8.5m/28ft
Detection up to 19m/62ft

DORI at installation height of 3m/10ft
Identification up to 3,5m/12ft
Recognition up to 6,5m/22ft
Observation up to 12m/40ft
Detection up to 28m/92ft

DORI at installation height of 3m/10ft
Identification up to 1m/3ft
Recognition up to 4m/13ft
Observation up to 7m/23ft
Detection up to 19m/62ft

FLEXIDOME IP panoramic 7000 MP 360°

FLEXIDOME IP panoramic 7000 MP 180°

FLEXIDOME IP panoramic 5000 MP 360°

Fig. 10: DORI - Detect, Observe, Recognize, Identify

At the same distance, a 12MP camera with a standard 70° lens provides much higher PPM / PPF than a 12MP camera with a 360° panoramic lens. This is an important consideration when deciding to use fixed, PTZ or panoramic cameras. When full situational awareness is required, you'll need to install a panoramic camera.
But when identification is a key requirement, then you'll need to install a standard or PTZ camera. A 360° panoramic camera allows you to see everything in a single image; while a PTZ camera only shows a part of the full situation. The image below shows the difference between full situational awareness and limited awareness based on the DORI criteria for both a PTZ and panoramic camera.

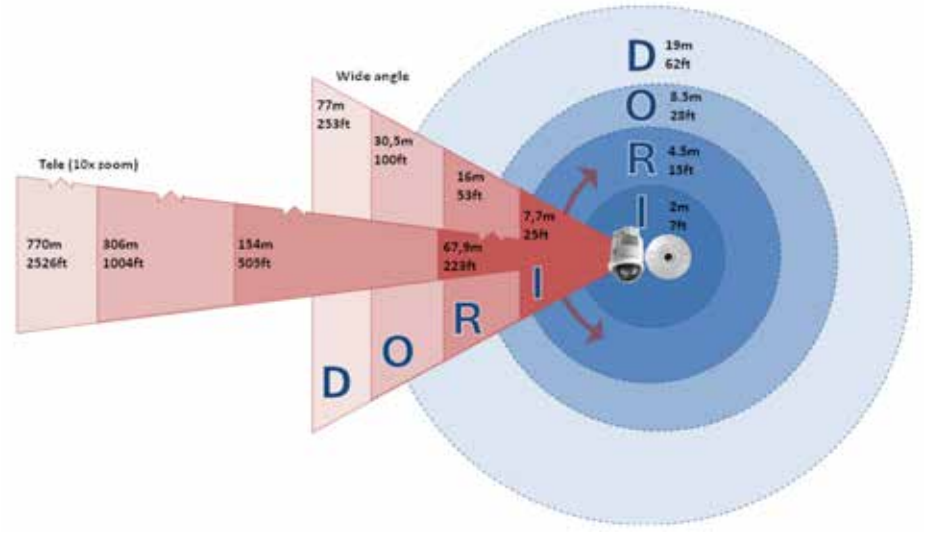

Fig. 11: The differences between full situational awareness and limited awareness based upon the DORI criteria

Easy to install and great aesthetics

Both cameras are designed for easy installation. The FLEXIDOME IP panoramic 7000 MP has a unique twist-click mechanism. It can be installed in a fraction of time needed for other cameras. The low profile of the camera makes it exceedingly suitable for installations where aesthetics and discrete video surveillance are important. The FLEXIDOEM IP panoramic 5000 MP, which is the smallest panoramic dome in the market, is also easy to install and comes with a convenient surface mount box. Updating the firmware with the latest features can be done remotely. Also, thanks to their ONVIF conformance, these cameras work seamlessly with third party video management software and recording solutions.

Applications

Retail

In-store surveillance, cash registers, shops, supermarkets, etc. One-shot overview, multiple areas of interest, monitors and records the entire space and every shop rail. Tracks people from entering the store until they reach the cash register.

Airports and government

Waiting areas, entry halls, ticketing, open areas, customs area, etc. Large area overview, track movements in an open area, multiple areas of interest in ticketing/ customs area/ waiting area. Entire queues can be monitored and displayed in a single image.

Offices and warehouses

Warehouse aisles, desk areas, open-plan offices, pick-up lanes. Large areas, lots of movement, long aisles. A warehouse contains tens to hundreds of long lanes of stock racks. To monitor an entire lane, a typical installation consists of two cameras for each lane, each facing a different direction.

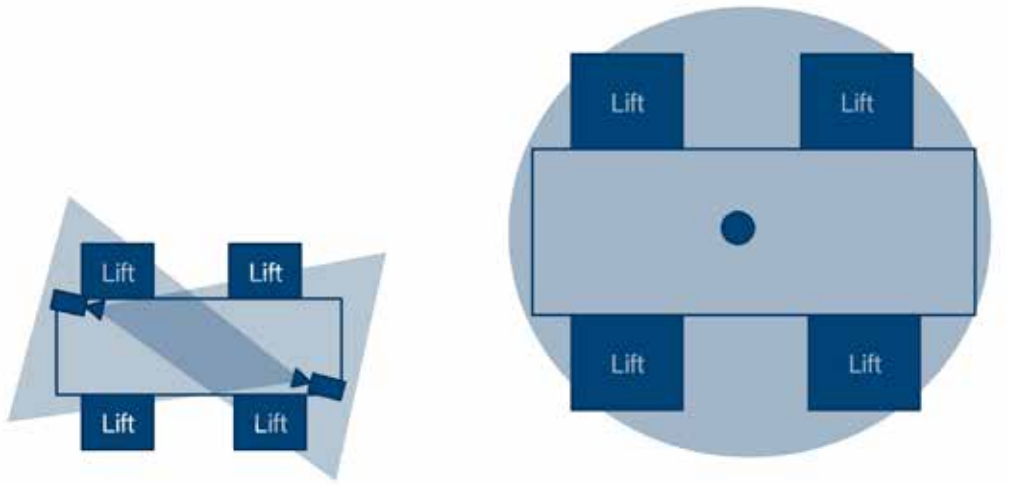

Fig. 12: Monitoring a lift lobby with fixed or PTZ cameras or a panoramic camera

Bosch Security Systems
To find out more about our IP video solutions and technologies go to www.boschsecurity.com/hdsecurity

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