Rating Camera Performance

Long-Range Factors

The difficulties in image quality comparisons.

There are a great many variables that affect the image quality of long-range cameras. Some of these variables are straightforward and measurable, but many are not. Likewise, some of these variables are controllable while others are not.

First off, there are the physical components of the camera. Starting with the build of the lens, each lens will vary in how much it magnifies the image (which is always specified), how much light is passed through the lens (which is sometimes specified), and how sharply and accurately the lens focuses that light (which is rarely specified). These specifications not only vary greatly from model to model but even slightly from lens to lens of the same model. Then you have the image sensor that captures that focused light. These vary by resolution (which is always specified), sensitivity (which is specified but not measured equally), sensor size (which is vaguely specified based on approximate 1950s equivalents), image processing (which varies by manufacturer) and color accuracy (which is never specified). So just in the physical components of the camera there is a lot of wiggle room for two cameras with exactly the same specifications to have fairly different levels of performance.

Then you have atmosphere and weather. Even in the best conditions, the air you're looking through is made up of molecules that degrade the image by hindering the transmission of light. Humidity, rain, snow, dust and fog will reduce the image contrast, and atmospheric turbulence from heat variations throughout the scene will cause distortions in the image. The further you're looking, the more these problems are amplified, and these factors differ not only from location to location, but even minute by minute.

Note that these atmospheric variables affect all surveillance cameras. All cameras are designed to capture a specific range of wavelengths (such as VIS, NIR, SWIR, MWIR and LWIR). Any two cameras using the same wavelength of light will suffer the same atmospheric limitations. It's important to keep in mind that atmosphere and weather will affect real world performance more than what is seen in most demo videos, which are often picked from moments of ideal atmospheric conditions.

To keep things fair and simple, we use a measurement called Pixels Per Meter (PPM) to compare camera performance, explained on the following page. It helps to think of PPM kind of like gas mileage. It gives an idea of the performance you can get under optimum controlled conditions, but many factors (driving habits, snowy roads, traffic conditions) might make it unlikely to achieve those results regularly in the real world. That doesn't prevent it from being a helpful benchmark that we can use to compare competing models in a fair and controlled way.

Rating Camera Performance

Pixels Per Meter

For comparing cameras and setting desired performance levels, we've found the simplest method is to use is pixels per meter (PPM), which is a measurement that defines the amount of pixels of definition across a 1m width at a specified distance from the camera. It's a simple measurement that provides a fair comparison of the long-range magnification capabilities of each camera and avoids the essentially useless X-factor numbers that are misleading to customers (see sidebar). It is also an objective measurement of detail that can be agreed on by multiple parties.

Pixels per meter is calculated using two measurements:

Field of View

The field of view (FOV, also called angle of view) is the width of the scene that a camera detects on its sensor. It is determined by the focal length of the lens in relation to the sensor size. Longer lenses or smaller sensors produce narrower fields of view, while shorter lenses or larger sensors produce wider fields of view.

A smaller field of view means that a camera is more "zoomed in" (to use a term that most people are familiar with). For example, a camera with a 90° horizontal field of view (HFOV) will see a 1000m wide section of a wall that is 500m in front of it. If you then adjust that camera's HFOV to only 1°, it will fill the screen with an 8.7m wide portion of that same wall. This second "zoomed in" field of view is what customers are looking for when they want a camera that can see a long distance. They want a narrow field of view.

Sensor Resolution

The other contributor to long-range camera performance is the sensor resolution. This determines the level of detail within a camera's field of view. For example, using the 1° HFOV result from above, a newer HD sensor and an old analog CCTV sensor will both produce images that fill the screen with 8.7m of the wall. The analog sensor has a horizontal resolution of 640 pixels, which means it displays 640 segments of detail across that 8.7m scene. This works out to 73.5 pixels per meter (640 ÷ 8.7). The HD sensor on the other hand, with a horizontal resolution of 1920 pixels, provides 3 times that level of detail with a value of 221 pixels per meter.

The images to the right show the importance of taking resolution into consideration. Using the same hypothetical cameras from the previous example, a North American license plate would take up 3.5% of the screen width on both cameras (it would be the same field of view), however the older analog sensor would render that plate with only 242 pixels (22×11), while the HD sensor would render it with over 2,200 pixels (67×33). This distinction is the difference between a blur of pixels and a clearly readable plate.

The X number does not determine how far a camera can see

When a camera's zoom range is displayed as "10X" or "39X", this is communicating the wide to narrow ratio of a camera's zoom capabilities. These numbers do not tell us how small a field of view the camera will have. In other words, the "X" numbers are not measurements of how "far" it can see and can not be used to calculate this information.

For example, a lens with a zoom range of 5mm to 500mm would be a 100X lens, because it can zoom to 100 times its widest focal point. Yet a lens that measures 500mm to 1000mm would only be a 2X lens, even though it "sees" twice as far as the 5-500mm lens does.

License Plate @ 73ppm (22×11 pixels)

License Plate @ 221ppm (67×33 pixels)

Rating Camera Performance

DRI & DORI Explained

If you've done any research comparing thermal cameras, you're likely to have come across the term "DRI", which is often used to compare performance between thermal imaging cameras. DRI stands for Detection, Recognition and Identification, however it's important to understand how those terms are defined, as they're likely to mislead many customers with unrealistic expectations. (We explain these definitions in more detail on the following page.)

As for more common color surveillance cameras (visible/NIR), there is another standard that sounds similar to DRI, but is different in its definitions. This standard is called DORI, which stands for Detection, Observation, Recognition and Identification. While most of the terms share the same words as DRI, it's important to recognize that their specifications are quite different.

VIS/NIR (with ZLID™ IR illumination)

Thermal Imaging

Visible/NIR vs Thermal

Visible/NIR refers to standard surveillance cameras that utilize the visible light wavelength and the near infrared wavelength to produce color video images by day and low-light black and white images at night. Thermal refers to cameras that operate in the mid-wave or long-wave infrared wavelengths where radiated heat is transmitted. Thermal cameras detect the "heat signatures" of objects in the scene and produce an image based on their apparent temperature.

These two technologies are quite different. They differ not only in the look of the images they produce but even more in how those images can be useful in surveillance. Thermal imaging excels in the detection of threats or targets, but falls short if you're wanting detailed images of those targets, whereas VIS/NIR imaging can provide excellent detail for identification of long-range targets while being much harder to use for detecting threats in many scenes.

This is why we build many of our camera systems with side-by-side thermal and VIS/NIR imaging. The ability to view both of these imaging feeds simultaneously is a huge benefit for most clients.

The table to the right shows the difference in common detail requirements for each standard in pixels per meter. The following pages explain and illustrate why these differences exist.

	DRI (Thermal)	**DORI** (VIS/NIR)
Human Detection	1–3 ppm	25 ppm
Human Recognition	3–7 ppm	125 ppm
Human Identification	6–14 ppm	250 ppm
Vehicle Detection	1 ppm	25 ppm
Vehicle Recognition	2–3 ppm	125 ppm
Vehicle Identification	5–6 ppm	250 ppm

Thermal Imaging Ranges

DRI Ratings Explained

Detection, Recognition, and Identification (DRI) are a set of standards developed for the US Military to compare the performance of thermal infrared cameras. This model, also referred to as the Johnson criteria, has become the universal standard for measuring thermal cameras.

What is DRI?

DRI is a universally accepted set of standards that attempts to provide a means of measuring the distance at which a thermal sensor can produce an image of a specific target. These standards were initially developed by the US Army in the 1950s and unfortunately have not been updated much to account for newer technology with larger theoretical ranges that are less likely to be achieved in the real world.

The model is based on a 50% probability of achieving the following objectives, under ideal conditions. Please read each definition as they may not match what you would expect from reading the terms alone.

Detection

Detection refers to the distance at which a target initially appears in the image. This “target” is something out of the ordinary that is warmer or cooler than the ambient environment. Specifically, it will be visible on at least two pixels, so there will not be enough information to confirm what the target is at this distance, just that something is there.

Detection (human)

Recognition

Contrary to what might be expected, recognition does not mean that you can recognize an individual. Recognition refers to the distance at which you can determine an object’s class (is it human, animal or vehicle).

Recognition (human)

Identification

Identification refers to the distance at which you can differentiate between objects within a class. For example, identifying the type of vehicle (truck, SUV, or car) or whether the human is a soldier or civilian.

Identification (human)

Note that these distance measurements are based on a 50% probability and do not take any atmospheric conditions into consideration. Weather is almost never ideal so in real use these distances are almost always shorter than specified.

Thermal Imaging Ranges

DRI Detail Levels

An outdated specification

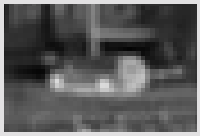
So the terms detection, recognition, and identification can be misleading, especially to end users who do not have a military or electro-optics background. To make matters worse, the original 1950s specifications were based on old sensors and screen display technologies. The increasing resolution of thermal sensors has shrunk the size of the DRI areas to tiny specks of white on the screen.

For example, our standard uncooled thermal sensors have a resolution of 640×480, which is over 300,000 pixels. Human "detection" only requires the target to be visible on 3–4 of those pixels. This is an extraordinarily small portion of the screen that can easily go unnoticed by the human eye. In fact, if this page were the size of your video feed, the area required for a human detection rating would be equivalent to the size of this rectangle:

This area becomes even smaller when you consider our HD sensors, which have resolutions over four times larger at 1280×1024 (over 1.3 million pixels).

Even when magnified, the amount of detail visible at the DRI distances is not as high as one might expect, as seen in the chart below.

DRI Requirements

	Detection	Recognition	Identification
Human	**3.5 pixels by 1 pixel** (Something is there)	**11 pixels by 3 pixels** (A person is there)	**23 pixels by 6 pixels** (The person looks like a civilian)
Vehicle	**2 pixels by 2 pixels** (Something is there)	**6 pixels by 6 pixels** (A vehicle is there)	 **12 pixels by 12 pixels** (The vehicle looks like a minivan)

Note that while it may seem impossible to tell that a human or vehicle is present in some of these images, it's often the movement of pixels in an area that makes it more obvious that an object is present. In addition, these standards were developed with trained professionals in mind, who will be able to spot activity much easier than a civilian.

Thermal Imaging Ranges

Alternate Methods

The examples on the previous page show simulated detail levels at the distances Infiniti uses for DRI, but it's important to know that different manufacturers may use different methods to determine their DRI numbers.

For example, L3 and FLIR have cameras that are almost identical in specification and should be within 5% of each other, but due to different assumptions on the conditions and atmosphere, one is rated for 21km of detection while the other is rated for 52km. Clearly these ratings are too arbitrary for proper comparison which is why for the sake of transparency and simplicity, Infiniti bases our DRI numbers on pixels on target, however pixels on target is not the only method available.

NVThermIP

The US Army has an updated thermal ranging model called NVThermIP, which is more mathematically sophisticated in order to yield more accurate results. It requires inputting a variety of values that specify the camera lens, detector, framing and sampling electronics, signal processing electronics, viewing display, atmosphere, target and task. The problem is not only are these a lot of inputs, but quite often those values aren't even known. In addition, there are so many variables and equations at play that it's often unclear what's going on.

Pixels on Target (PPM)

Used by many manufacturers as a simpler alternative to NVThermIP, this method is done by calculating the number of pixels needed across the critical dimension of the target and then converting that value to the required pixels per meter. The sensor and lens measurements then allow us to easily calculate the pixels per meter performance of the camera across a full range of distances and calculate the distance where each level of detail is achieved.

Of course a drawback to this method is that variables like weather and atmosphere are not included in the calculation, but those values are rarely accurately known anyways.

At Infiniti, we calculate the critical dimension by using the square root of the target height multiplied by its width, resulting in a critical dimension measurement for a human at 0.95m and a military vehicle at 2.2m. Using the Johnson Criteria of one line pair for detection, 3 line pairs for recognition and 6 line pairs for identification, and assuming one line pair is equal to two pixels, the required DRI values for PPM are as shown in the chart to the right.

Human Detection	2.1 ppm
Human Recognition	6.3 ppm
Human Identification	12.6 ppm
Vehicle Detection	0.9 ppm
Vehicle Recognition	2.7 ppm
Vehicle Identification	5.5 ppm

Visible/NIR Imaging Ranges

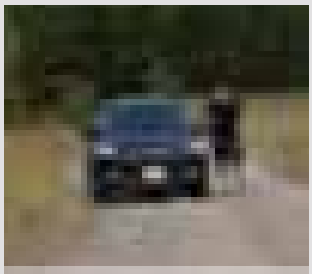
DORI Ratings Explained

The DRI system helps to specify those terms for thermal imaging so that everyone is on the same page, but visible (color) imaging performs very differently. While two pixels on a screen might be enough to count as “detection” on thermal, that level of detail would be nearly impossible to use for detecting a target on a visible imaging system, unless you already knew exactly where to look.

So we need a different set of values for visible color imaging, but as the previous pages show, one of the difficulties that arises when trying to specify detail requirements is that everyone’s idea of adequate detail is different. The problem with using terms like “recognize” or “identify” is that people get an idea in their head of what level of detail that would be and it often differs.

Since perceived detail levels vary greatly, we use the pixels per meter (PPM) measurement to specify the amount of detail needed for each of our clients. We highly recommend specifying your camera performance requirements in PPM, as it makes things clear for everyone involved. Shown below are examples of a few different PPM levels; we’ve also created a document that can be sent out upon request that displays a wider range of detail levels.

Human & Vehicle at
2ppm



Human & Vehicle at
10ppm

Human & Vehicle at
100ppm

Human & Vehicle at
175ppm

An International Standard

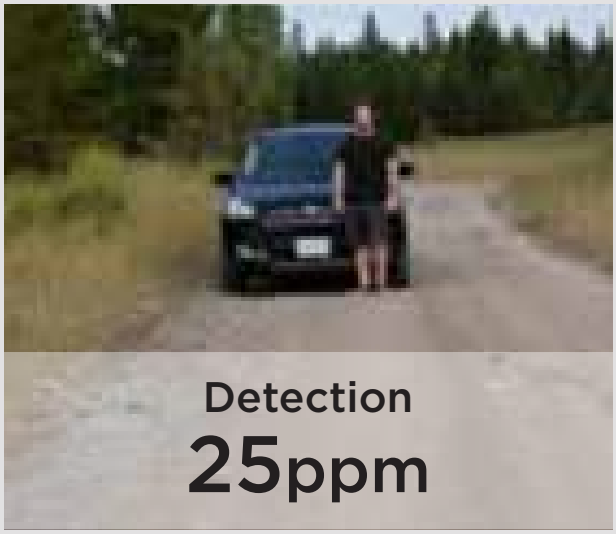
If you’re unsure of what level of what PPM levels to specify and are wondering what others use, we refer you to a widely used standard for detail level requirements in visible imaging surveillance systems.

The DORI standard was developed by the International Electrotechnical Committee (IEC), European committee for electrotechnical standardization (CENELEC) and British Standards Institution (BSI). The IEC EN62676-4: 2015 International Standard defines specific levels of detail for Detection, Observation, Recognition and Identification (see details on following page).

Whichever PPM values you decide on, using specified PPM values makes it possible to select specific cameras and calculate their PPM performance to verify that it will provide the performance needed for your application.

Visible/NIR Imaging Ranges

DORI Detail Levels



Detection
25ppm

At the detection distance, the operator will be able to determine a human presence, although few details about that human will be visible.

Observation
62ppm

At the observation distance, some characteristic details of the individual, such as distinctive clothing, can start to be seen.

Recognition
125ppm

At this distance, verify with a high degree of certainty whether an individual shown is the same as someone you know. License plates also become legible at this distance under good conditions.

Identification
250ppm

The ability to positively identify a person beyond reasonable doubt. This level of detail provides sufficient image quality to identify an individual or clearly read a license plate.

The examples here simulate the amount of detail if you were to digitally zoom into the image. **Please note that these image simulations assume optimum imaging conditions, however many factors such as atmospheric conditions, heat waves, available light, subject motion or camera shake can degrade image clarity, and most of these issues are amplified at longer distances.**

INFINITI WHITEPAPER

Get the Best Performance

Customized Solutions

Just scratching the surface

We wrote this white paper in an effort to explain the rating systems we use while also giving end users an idea of the actual performance they can expect from their thermal and visible/NIR cameras. That said, this information just scratches the surface of the many considerations that go into building long-range surveillance cameras.

In addition to VIS/NIR and thermal, Infiniti also offers active IR illumination, SWIR, and other sensors such as LRF, Radar and more. We do not limit our customers to any one technology; rather we custom build solutions that typically use multiple sensors depending on the project.

There are also many additional aspects to consider when building a camera system, such as cooled vs uncooled thermal, size and weight, stabilization, connection and control, environmental and ingress protection, international trade regulations and more; all of which need to be considered alongside budget and availability.

At Infiniti we excel at designing customized systems to suit your specific needs. We can examine your situational requirements, location conditions and project budget and recommend the best system (or systems) available within that budget. We are also experienced in configuring multi-camera systems complete with multichannel recording, wired or wireless networking, access control, radar integration and more.

Contact us today for our expert advice on the ideal solution for you.

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