The Seductive Siren Call Of The “Megapixel Lens”
(And Why You Shouldn’t Listen to It)

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Have you heard the one about the 12 megapixel camera lens? You know, the one that is the perfect match for a 12 megapixel camera?

You haven’t? That’s because imaging-system designers haven’t been laughing as their exposure to this widespread hoax, one perpetrated by a majority of leading lens manufacturers, has continued to grow.

“Megapixel” lenses are a bit like “natural” foods. Buyers implicitly understand what the terms mean, except that they don’t. They can’t. The terms are meaningless in both contexts.

In early 2016, CBS News reported that “more than 60% of Americans buy products labeled ‘natural,’ but that, according to Consumer Reports, the ‘natural’ labels offer no clear meaning and are misleading consumers — with more than two-thirds of Americans thinking ‘natural’ means more than it does.” (January 27, 2016)

While the “natural” in “natural foods” has a slippery meaning, the term “megapixel” in “megapixel lens” is simply misapplied.

Misleading Moniker
Camera and sensor manufacturers are correct in characterizing their wares according to the number of megapixels they provide — with a megapixel generally understood to equal 1 million pixels (although the precise calculation, 2 to the 20th power, actually equals 1,048,576 pixels). Categorizing cameras and sensors by megapixels makes sense, because the term refers to the amount of pixels available on the sensor.

The more pixels, the greater the resolution — everyone is happy. If an imaging systems designer needs more resolution, he or she knows to choose a camera with more megapixels.

We get it: In the spirit of “more is better,” megapixels are sexy. They just have nothing to do with lenses and lens performance. It is not fair to describe a lens in terms of megapixels, and it is not right. In fact, it is flat out misleading.

We’re going to show you why “megapixel” is a nonsensical term as applied to lenses, and we’re going to help you cut through the megapixel noise and replace it with the important parameters within which you need to work instead to find the appropriate lens for your megapixel camera.

Getting It Right
We’re going to get to the bottom of this megapixel mislabeling by highlighting some sensor characteristics of some popular brands — good sensors familiar to a broad spectrum of imaging-system buyers — and examining them within the context of lens requirements.

First, look at the two On Semi chips in Figure 1, focusing first on the column in green. This column lists the value of the “Sensor Diagonal,” or the measurement of the chip from corner to corner. Both chips here have a sensor diagonal of 11mm.

Nyquist Limit = 454 Lp/mm
Requires a lens faster than f/1.0 to obtain full resolution.
of 11 mm, but one contains more than 4.5x the number of pixels on that same area.

Now look at the values in orange. Here are two Sony 12 megapixel sensors, a very common value. Move over one column and you’ll see that the pixel size of the first sensor is extremely small, under 2 microns. Very few lenses can even image a dot at 2 microns. Now look at the other one — 3.45 microns — still small, but easier to match with a working lens.

So why are we taking you through this eye chart? Because if your job is to buy the lens for the Sony camera system outlined above and all you are told by the lens manufacturer is that it has a 12 megapixel lens for you, you’re at high risk of buying a lens that won’t work well, if at all, within your imaging system. The same goes for the On Semi 13 megapixel camera sensor — if you didn’t know heading into your lens purchase that the pixel size was 1.1 microns, you’d be heading into a world of hurt. That’s because a sensor with 1.1 micron pixels implies a resolution limit of 454 line pairs per mm, which is huge! If you wanted to image a dot in object space to fall exactly on one pixel, dot for dot or dot for pixel, you would have to have a lens of f/1 or even faster, and you won’t find one easily.

Which leads to our first tip: Ignore the megapixel count, care about actual pixel size. Understanding the pixel size will put you on the path to finding a lens that will have enough performance — or MTF — to form a spot at that individual pixel size.

Now look again at the two Sony sensors. If you had to pick a lens for these 12 megapixel cameras, check out the difference in the sensor diagonal between them. It’s almost 2:1! If a lens buyer only had “12 megapixel lens” to go on to choose a lens for one of these cameras, he or she might get lucky. A 12 megapixel lens for the first Sony sensor could possibly handle the 8.61 mm image circle/sensor diagonal (our experience is that many 12 megapixel lenses are only corrected for an 8 mm image circle), but, even if it could, it would require divine intervention for this lens to create a large enough image circle for the second one.

The consequences here are significant across industrial-imaging applications, from robotic vision to wafer and food inspection to security and military applications. Understandably, the cameras you are purchasing for these imaging systems are all designated in megapixels, but if you bought a “12 megapixel lens” for the Sony sensor with the 17.6 mm diagonal and the lens was only designed for a 2/3” sensor format (11 mm diagonal/image circle), you could blacken all the corners of the image — you wouldn’t have imagery across the whole view.

Which leads to tip two: Understand the physical size of the sensor, so that when you pick a lens the lens can form an image that will cover the whole sensor.

f-stops and Airy Disks

Another way of understanding the disconnect between the promise of megapixel image perfection and the limits of lens performance is to consider the Airy disk, the theoretical smallest point upon which a beam of light can be focused.

The Airy disk is the smallest point upon which a beam of light can be focused. The disk comprises rings of light decreasing in intensity and appears similar to the rings on a bull’s-eye target. The center bright spot contains approximately 84% of the total spot image energy, 91% within the outside diameter of the first ring and 94% of the energy within the outside diameter of the second ring and so on.

The following equation shows how the Airy disk diameter (ADD) is calculated:

$$ADD = (2.44)(f/#)(\text{wavelength})$$

We bring up Airy disk diameter because it has implications on image resolution and lens choice. Today, the individual pixel size on many megapixel sensors is often smaller than the size of the Airy disk, which leads to phone calls like this:

“Stu, I’m using an f/5.6 lens, which produces a near 9 micron Airy disk, so why aren’t my images clear or not resolving what I require?”

When I dig deeper and find that the pixel size they are using is
1.94 microns, I have to tell them that at f/5.6 they aren’t actually imaging off an individual pixel. The best the lens can do to form a single spot in object space is to use a cluster of four pixels.

So what are the implications? You tell me. You went out and specifically bought this sensor for its wonderful number of megapixels and pixel size, and you selected a lens that is not capable of forming a spot size commensurate with the pixel size, effectively throwing away your resolution. There was no sense going with that sensor — it was a bad choice.

Or, put another way, you purchased a lens that isn’t really usable. You are getting an image, but are you really seeing everything you wanted to see? You are not really utilizing all of the pixels: They are getting eaten up by the large Airy disk formed by the lens. You may think you are getting 12 megapixels of resolution, but in fact you are not, you are getting false resolution.

Be An Informed Buyer
Five days a week, we get calls asking for lenses based on the number of megapixels in a camera’s sensor. And five days a week, we tell our clients and prospects, this is a non-starter for making the right lens selection for their system.

No matter the application, cameras today are labeled in megapixels. We’re fine with that. But when you go to put the proverbial tires on the car by choosing your lenses for your vision system, the person making that critical selection should put blinders on to the word megapixel and only key in on two factors — individual pixel size and sensor dimensions.

Unfortunately, many optical companies are making that difficult. By embracing the slick, but entirely meaningless, megapixel categorization of lenses, they are leading unwary buyers on a road to nowhere. And with no standardization of data sheets and without enforcement of meaningful lens-specification standards, it’s up to the buyer to know in advance what matters most and what questions to ask before making the purchase.

Be that informed buyer.

KEY TAKEAWAYS
1. Ignore the megapixel count, care about actual PIXEL SIZE. Understanding the pixel size will put you on the path to finding a lens that will have enough performance — or MTF — to form a spot at that individual pixel size.

2. Understand the physical size of the sensor, so that when you pick a lens the lens can form an image that will cover the whole sensor.

About Schneider Optics
Schneider Optics is the U.S. subsidiary of the world-renowned German optical manufacturer, Schneider-Kreuznach. Schneider has been producing the highest quality optics on the market for over 90 years, offering solutions for large-format photography, photo enlarging, motion picture projection, optical filtration, and industrial applications. In 2000, Schneider Optics acquired Century Precision Optics, adding its over 50 years experience manufacturing superior attachments for film and video.

Schneider Optics has offices in Hauppauge, NY, and Van Nuys, CA, and a network of hundreds of dealers around the globe, ready to assist you with any of your imaging needs.

Joseph Schneider founded the company in 1913 in Bad Kreuznach, Germany. Since that time the Schneider factory has been constantly modernized, always remaining state-of-the-art. The factory is fully compliant with ISO 9001 standards. Its U.S. subsidiary, Schneider Optics, was founded in 1972.