John Snell, Principal
The Snell Group

Breakthroughs in Infrared Camera Prices and Performance!

Building and Roof Applications

I remember the first time I looked through an infrared camera very clearly. The house we were working on, back in the early 1980s, was a disaster: a partially-insulated, 3-story, balloon-framed Victorian. I didn't know much about infrared thermography, but I hired a guy who said he did who came with a funny looking camera (a Hughes Probeye™) that cost more than I made in three years. It was incredibly awkward to use and the thermal image it produced was fuzzy but with imagination decipherable. Even so I was amazed!

A lot changed after that, but slowly. Cameras did get better but they also got heavier. Prices "came down" but remained well out of reach of most building professionals. Thousands of people began using the technology but it still was not widely used on every job.

The author using a modern $60,000, cryogenically-cooled, "portable" IR system in the early 1990s.

The past two years, however, has seen inconceivable breakthroughs in the market. The price has dropped by an order of magnitude, image quality has improved at the same rate, and cameras are finally being designed with the end user in mind. For example, I recently used a new camera that looks just like a cell phone. It is many times more powerful than the one I first used twenty years ago and a quarter the price. It is no wonder that once again – and quite suddenly – infrared thermography has become one of the hottest tools for building diagnostics.

Literally hundreds of lower-cost cameras were purchased last year to diagnose basic energy-related problems and even more were used for new, specialized buildings applications such as pest-management and moisture detection. Another recent, exciting development is the use of thermography by insurance companies to verify that moisture-damaged buildings have been restored to a dry condition.

Technological breakthroughs have come from a huge push by the US military to expand the use of thermal imaging and this has "trickled down" to benefit the civilian market. Good quality detectors are readily available and camera suppliers have moved quickly to incorporate them into remarkable new system designs. Competition among these suppliers, stagnate in the 1990s due to corporate mergers, is once again stiff and informed consumers are the beneficiaries.

What features are important?

The ideal infrared camera for today's building scientist does not necessarily need to be "top of the line." A wide range of features is available in models ranging in price from $3000 to $10,000. As complex as they may seem, infrared systems, like any camera, are made up of a few basic components: lens, detector, processing electronics, display and controls.

New IR systems are well-designed and easy to use with a wide range of feature sets and prices to fit most budgets.

Specifications for cameras are often confusingly stated and difficult to compare and, given today's highly competitive market, some sales people may use specifications to push or pull a product. While some specifications, such as thermal sensitivity and detector size, may be useful in evaluating performance, in the end, how the camera functions and feels while you perform your work is more telling of its value. If you are considering purchase of any IR camera, try it (under field conditions) before you buy it and compare it to others. That said, the good news is there are many great products in the market and, when they meet your needs, some represent values that were previously unimaginable.

Let's look more closely at specific camera components and some of their important features of cameras in general.

► Thermal sensitivity is no longer the big issue it once was because today's detectors can typically resolve temperature differences of .1°C (or 100mK) or less at 30°C, a remarkable feat! For buildings work, sensitivity is important and more sensitive is better. At least one supplier is selecting their most sensitive detectors, as low as 30 mK, for cameras they're marketing especially to building professionals.

► Today's detectors, which produce an electrical response when infrared radiation is focused on them, are generally one of two types: amorphous silicone (aSi) or vanadium oxide (VOX). While there are differences in performance, either can perform well for building diagnostics work. Neither requires cooling, a big relief to anyone who used a cooled system in the past. They also detect longwave infrared radiation, far preferable for use out of doors in the sunshine than earlier shortwave systems.

► Regardless of sensitivity, images of surfaces with temperatures below approximately -18°C (0°F) will not be as good as images of warmer surfaces. Unfortunately, specifications are typically not available for these low-temperature conditions. For the most part this is not a huge limitation, however, as we are generally inspecting very cold building surfaces only a small fraction of the time.

► Most cameras are specified to operate at fairly low temperatures; this does not guarantee image quality, only that the camera will function. Clearly batteries will not last as long in cold weather, but additional batteries are usually not expensive. Avoid storing IR cameras in a vehicle during cold or hot weather as this can result in serious damage to the electronics and batteries.

Cameras also have a temperature range in which the accuracy of the radiometric temperature measurement is assured. For most building applications, radiometric measurements are not essential so this is less of an issue. Most, if not all, of the cameras on the market at this time should perform well out of doors in all but bitter, Arctic conditions.

► Being able to measure radiometric temperatures can be very useful for building scientists, however, it is by no means essential for most of us. In the past radiometric systems were very expensive but that is not necessarily true anymore. Several systems are "fully radiometric," meaning the entire image is calibrated for temperature measurement, while others can make a radiometric measurement only at a single spot in the center of the image. Either can work well. Separate spot radiometers are also available to supplement a non-radiometric IR camera; models suited to building diagnostics work are available for several hundred dollars. Think about what your real needs are and, if you need radiometric capabilities, buy accordingly.

► An infrared camera lens will have a fixed field of view (FOV), rather than being a "zoom" lens. The wide-angle lens is most useful inside buildings; of course, this is where much of the work is typically done. Outside, especially for large buildings, a narrower FOV may be more useful as distances involved are typically greater.

The quality of the images produced by modern IR systems is remarkable. Missing and poorly installed insulation is easily seen.

The FOV for lens is specified in degrees for both horizontal and vertical views. Typical for outdoor work is a "normal" lens with an FOV approximately 20°x20° while indoors a wide-angle lens with an FOV 40°x40° will perform well. Unless you are working exclusively inside, where you should probably have a wide-angle lens, or on larger buildings from the outside, where you'll probably want a normal lens, one lens will often suffice for both types of work.

As with any camera, the lens determines not only the FOV at a given distance, but also, along with the detector size, it defines the level of detail you can resolve in the image, much as an eye chart helps us measure what we can see. Again, except for work on large buildings, spatial resolution is usually not a huge concern because we can easily move closer.

While zoom lenses are not available, many IR cameras have an electronic zoom capability that simply magnifies the image. While this can be a useful feature, it does not result in any improvement of resolution and would typically not be a compelling reason, by itself, to buy one camera over another.

► IR systems come with three choices for focusing: manual, motor assisted, or fixed focus. While new users often develop a preference to one focus type or the other, each can work well and yield great images that are in sharp focus. Interestingly, each also has its own set of limitations, although none are particularly problematic.

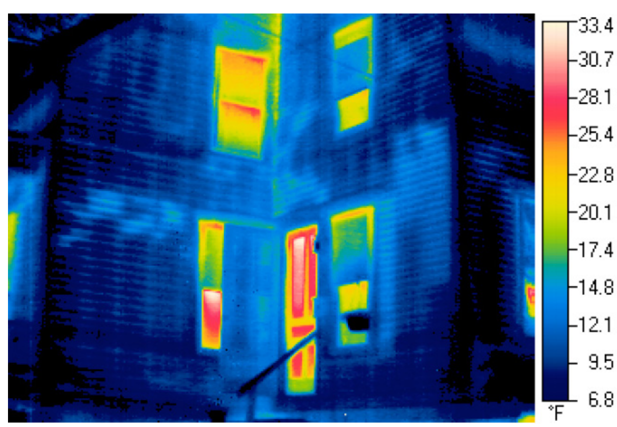
The depth of field for new lenses is typically very narrow. Focus, regardless of the focus mechanism, is critical to getting good images and, for radiometric systems, for getting good temperature measurements as well.

► An infrared system, as is also the case with a digital visual camera, now uses a matrix of very small detectors assembled in a rectangular array at the focal plane; for this reason they are termed focal plane array systems or, in the jargon, FPAs. Two array sizes are in common use, 160x120 (19,200 detectors) and 320x240 (76,800 detectors). The array size as well as the lens used determines the spatial resolution of a camera at any given distance. Obviously, IR camera resolution is a long way from the 3-8 megapixel resolution we are used to in visual digital cameras but it is also very adequate for most building diagnostic work.

Early 160x120 systems were often quite "pixilated" compared to 320x240 arrays. Better designs and image processing, however, have resulted in both array sizes yielding images that are of very high quality and, interestingly, often remarkably comparable. Until recently the larger arrays were significantly more expensive, but the difference is much less in the past year.

While it is generally true that larger arrays are better, two factors should be considered carefully. First, and foremost, is image quality. This is somewhat subjective and depends not only on the array size, but also the lens, processing electronics and the display. The best advice is to try before you buy – under your typical work conditions.

The second thing to consider is what spatial resolution is needed, meaning what is the smallest detail you need to resolve at the given working distances. Remember, this is based on the detector and the lens used. As stated earlier, resolution is typically not going to be a limiting factor unless you are viewing large buildings outside at great distances where you simply cannot get closer. If your



Another view, under different conditions, of the same house shows how results can vary as circumstances change. Note the use of a "rainbow" palette and the inclusion of the radiometric temperature scale.

work is mainly on large buildings from the exterior, a 320x240 system is probably what you should be using.

► Spatial resolution is usually specified as an angle (in milliRadians or mRad) called Instantaneous Field of View (IFOV); stately simply, IFOV is a projection of the detector through the lens onto the scene and the relationship is IFOV (in radians) x distance = spot size. Thus, using a system with an IFOV of 2.0mRad at a distance of 20 feet you could resolve detail as small as, approximately, ½" in size. As the IFOV specification increases, spatial resolution decreases.

► Images are stored either on removable media, such as a PC-card, or in the flash memory of the camera. When considering a camera, think realistically about how many images you need to store before downloading to a computer; typically several hundred or fewer will be sufficient. Downloads through a USB or FireWire port are, for the most part, fast and painless.

► Most, but not all, IR cameras also have the capability to output a live analog video signal that can be played on a monitor or recorded on a VCR or camcorder – *if* it has video input. Digital video is available only on very high-end IR cameras at this time, but expect that will change in the future.

► The "dynamic range" of the stored image is a very important specification to consider. A large dynamic range (12-bit or 14-bit), which means image thermal level and span (essentially contrast and brightness) can be manipulated after capture, is essential. An 8-bit image cannot be adjusted after it is stored and cameras with that limitation should probably be avoided.

► The basic adjustments on all IR systems are similar; the two most important are thermal level and span, essentially brightness and contrast. Controls for these and other functions may be buttons or pull down menus or a combination of the two. Some have automatic image adjustment modes that can work very well, although it is also important, in most cases, to be able to also adjust the image manually when needed. While the basic functionality of some camera designs is better than others, it should be possible to quickly become proficient at adjusting any of them to get great images.

► Digital *visual* image cameras are incorporated into a several IR systems. The primary benefit of these is that the IR and visual image files are electronically mated, a boon after inspecting a number of similar buildings in a day and having to create reports. Unfortunately, the image quality of these integrated visual cameras is often poor. Make sure you try before buying – at distances and with lighting conditions typical of your work.

It may be smarter to save your money and buy a good 3- to 5-megapixel digital camera instead even if you will have to be more careful about managing the separate visual and IR image files. The power of a good, high-quality visual image is being able to blow it up and clearly see some essential detail you may have overlooked at the job site.

Air wash along the edges of batt insulation produces a unique cold signature on the ceiling of this wood-frame commercial building.

► Some systems have the capability for in-camera voice or text annotation, which is electronically tied to the image file. This data can then be recalled later and inserted into the report document. Both these features can be very useful, but the lack of either should not alone necessarily cause an otherwise good system to be rejected. For better or worse, hand-written field notes probably will always be with us!

► Reports are typically created in custom software program, which can read the proprietary image format. Most come with a basic image download package that allows for them to be copied into various, non-proprietary formats and used in a document. Some report software, while useful, may be more than is necessary and can come at a considerable cost, often hidden in the total system cost.

► Many of today's IR systems display the image on generously sized LCD screens. These allow you to easily see the image and, when you want to, quickly show it to co-workers, contractors or owners who are looking over your shoulder. Beware, however, that many of these displays have limitations. First, they may not work well in bright light or direct sunshine; for most, however, this is not a "deal breaker" as only part of your work will be in these conditions. Second, some displays are fixed and cannot be tilted. This is a more significant limitation and one that should be considered with care as an adjustable display is useful, if not essential, for most building applications.

At least one supplier sells as a fairly high-priced, optional "heads-up display" that, while it looks very cool, should, for reasons of cost, safety and complexity, be considered only after careful trial and evaluation. FYI, this display can be purchased directly from the display manufacturer as well!

► Many who are considering purchasing an IR system will have a preference as to whether the image is color or grayscale. Here is the truth: depending on a number of complex, interactive factors – as well as some subjectivity – some systems work better in one or the other. Generally thermographers will work in either grayscale or a monochromatic color palette; reports often look more impressive in a full rainbow of colors but that palette is extremely difficult to work in. Most software programs allow for the image palette to be changed later one. As you evaluate IR systems, try them in all palettes to see which gives the best results.

► The frame rate of most cameras is either 30 or 60 frames per second (or Hz) but several cameras have slower frame rates. Despite the fact that some sales people may try to convince you otherwise, any of these will work fine for building applications with no perceivable loss of quality.

► Some suppliers have added "bells and whistles" that may or may not be useful such as a dewpoint indicator and emissivity lookup tables. Both can actually be misleading. Laser pointers may have value, but a separate pointer or flashlight can serve the same purpose at a much lower cost.

► Batteries have gotten better and better. Proprietary batteries tend to now be Ni-metal hydride or Li-ion, both of which will perform well, even if they may be somewhat costly. Other systems utilize AA-batteries, regular or rechargeable. If you will be doing much work in cold weather, consider buying an extra battery or two.

► Expect that any IR system will need repairs at some point. A general rule of thumb is to budget 10% of the purchase price for *annual* maintenance. Most are fairly rugged but should be treated with the same respect due any costly piece of electronics. Interestingly, some can be dropped from five feet with no damage or interruption of function! Regardless of the system, you'll want to protect it from dust and damp. A thin-film plastic bag works well as it is quite transparent to IR radiation.

Radiometric systems will need to be re-calibrated when out of specification. A simple procedure can be instituted to regularly check calibration; when necessary, re-calibration is then performed by the supplier. Unfortunately some suppliers recommend re-calibration annually. This is not only an unnecessary, often exorbitant, cost, it also offers no assurance the system is actually within spec the balance of the year.

IR Jargon and Terms

FOV: field of view, a measurement of the angle seen by the camera; the specification is typically given in degrees horizontal and vertical, such as 22° x 22°

FPAs: Focal Plane Array systems have a matrix of individual detectors.

Detector array: the detector array is a composed a number of individual detectors, typically 340 x 240 or 160 x 120 in size

Microbolometer: a FPA with a thermal detector that responds with a voltage change

MilliKelvin (mK): One thousandth of a Kelvin (or centigrade) degree

Radiometric: the response of the detector to IR radiation is calibrated so that temperatures can be inferred from the amount of radiation detected. If a camera is fully radiometric, temperatures can be read anywhere in the image. Others have only a center spot that is calibrated for measurement.

Sensitivity: a measure of the minimum temperature difference (in milliKelvin or mK) that can be detected at a given temperature, typically 30°C (86°F)

Spatial resolution: a measure of the ability of the detector to resolve small-sized details; the term Instantaneous Field of View (IFOV) may be used with the specification quoted as an angular measurement in milliradians (mRad)

Spot radiometer: temperature "guns" that measure radiation for a given spot and convert the data into a radiometric temperature value without a thermal image. While useful, these inexpensive ($100-1000) devices can have severe limitations with regard to spatial resolution and emissivity correction.

► Today's IR systems are definitely easy to use! Anyone who can use a conventional video camcorder or digital still camera can quickly learn to get good thermal images. Don't forget, however, that the accurate interpretation of the images requires not only good camera skills, but also an in-depth understanding of heat transfer, radiation physics, conditions for inspections and basic building diagnostics.

Buildings are very complex. Inspections are done with conditions that are often less than ideal. You must understand how that affects what you are seeing – and not seeing – in the thermal image. Without a solid foundation, you can expect to make mistakes. Don't kid yourself, some may be costly.

Good training options are available, but make sure the one you choose specifically covers the camera you have and your applications needs. For groups of 5-10 people specialized, onsite training focused on your needs and equipment probably makes the most sense.

Be wary too, of training companies that purport to "certify" those who purchase their products. Unfortunately much of this is just plain, old marketing hype. For better or worse, there are few, if any, meaningful industry requirements for building professionals. Hopefully this situation will change for the better in the near future. The true keys to proving you are qualified, rather than having a fancy piece of paper hanging on the wall, are getting appropriate training and documented experience.

Standards for conducting building inspections do exist and all thermographers should become familiar with them. The two most commonly used are *ISO 6781 Thermal insulation, qualitative detection of thermal irregularities in building envelopes, Infrared Method and ASTM C-1060 Standard practice for Thermographic Inspection of insulation Installations in Envelope Cavities of Frame Buildings*.

But …can we afford a camera?

With all of the features available, it is easy to become infatuated with a new IR system and forget your budget. Some manufacturers have cleverly priced their systems to make it easy to add on a long list of features – all at a price of course. Make sure you look at the total package price including lenses, reporting and/or analysis software, data storage cards, LCD view screens, batteries and training. This is an investment that must pay returns!

Even though very useable cameras are now available for far less than in the past, you should still ask, "Can I really afford an infrared camera?"

Consider the fact that a new IR system will last at least ten years. Even if you budget 10% annually for maintenance, the cost for the $15,000 system is $1650 per year over its life. If the system is used on 100 buildings each year, a low figure, the cost for the infrared camera is only $16.50 per inspection. Even with other associated costs, the total cost of a production inspection is probably less than $100 per building.

In other words, for the price of a moderate restaurant dinner for a party of four, a homeowner can have 100% assurance of the performance of their insulation and air sealing work or the fact that their home is dry after restoration. Gone are the frozen pipes or insidious ice dams so often associated with work that has not been inspected. Plus, at time of sale the owner has irrefutable documentation of the actual condition of the building.

If you are a contractor, an infrared pre-inspection of a job can mean things go smoothly and on budget because you quickly understand exactly how the building is constructed and performing. Inspections after the job is complete will virtually eliminate costly callbacks. For those in the restoration market, thermal images become the documentation needed to assure the building was dried completely prior to release.

IR view of the future looks good

The choices today for fully featured infrared systems costing less than $25,000 is astounding. And get ready because new technologies are in the works right now that will mean more, even less costly, choices soon for systems very well suited to building diagnostics work. As is the case with computers, however, the fact that the market is changing fast is not the reason to wait for things to get better or less expensive.

Analyze your current needs and see if today's systems make sense as an investment now. While there are many, often confusing or complex, choices confronting someone who is considering the purchase of an IR system, the good news is that it is hard to go wrong with any that are available in the market today. Do your homework, look at – and try! – several systems, and then buy one as soon as possible so you can begin to reap the benefits of this remarkable technology now.

The Snell Group™
Our Knowledge. Your Advantage.

Acquiring a New Infrared Camera

❐ Write down a list of your *real* needs, including addressing these questions, among others:
- What are your primary applications?
- How many people/departments will be using the camera?
- What is your budget?
- If you are a consultant, what do you need to compete?

❐ Conduct research to determine which suppliers may be able to provide products that will meet your needs
- Web research http://www.thesnellgroup.com/LinksOfInterest.aspx
- Look for feedback from other users in the Classifieds and Equipment Talk forum available at www.IRTalk.com
- Visit a nearby trade show where suppliers are exhibiting
- A Level I training course may be a good place to see many systems in use
- Call The Snell Group to discuss your needs and options

❐ Invite select suppliers to demonstrate their products to you – one at a time

❐ Set up a "race course" that allows you to test each camera as fairly and equitably as possible under conditions similar to those you will encounter on the job
- Have several different prospective users try each system
- Take notes and photographs of each
- Get written quotes for the exact system you need
- Ask for the best price available, and be honest that you are looking at others

❐ After evaluating the candidate systems, sit down with all players who need to be involved in the decision making process
- Stick to the facts first, "likes and dislikes" second
- Confused? Give us a call to talk
- If there is a clear first choice, ask again for "best pricing" and purchase
- If there is no clear first choice, consider renting both systems for a month

❐ Get the training you need and get started using this remarkable technology!

John Snell of The Snell Group, Montpelier, Vermont, has trained thousands of people to use the technology in the past 20+ years. The Snell Group works with all the major suppliers of IR systems to provide their customers with training, while remaining 100% independent of the sale of any particular product.