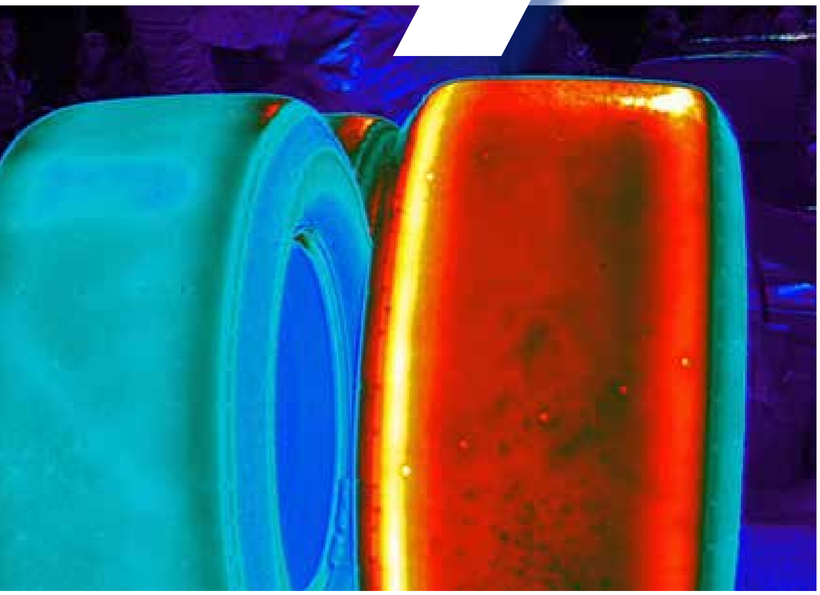
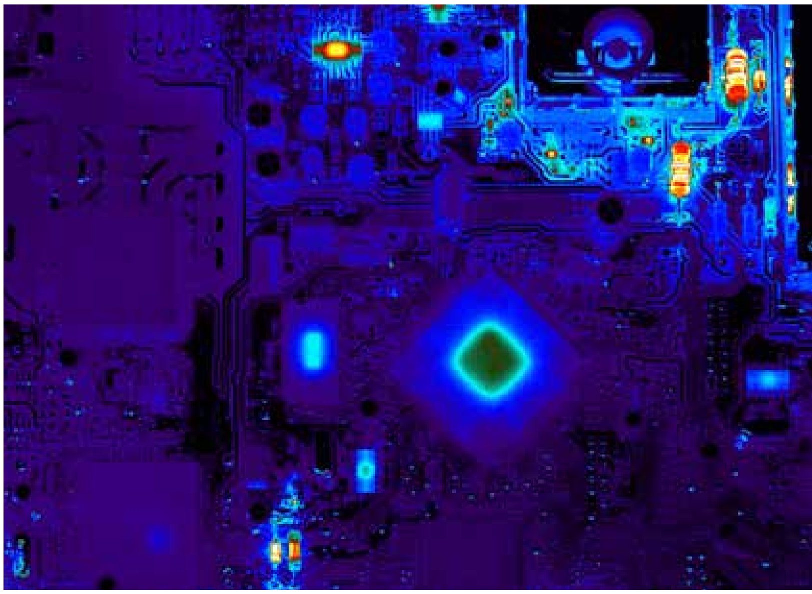
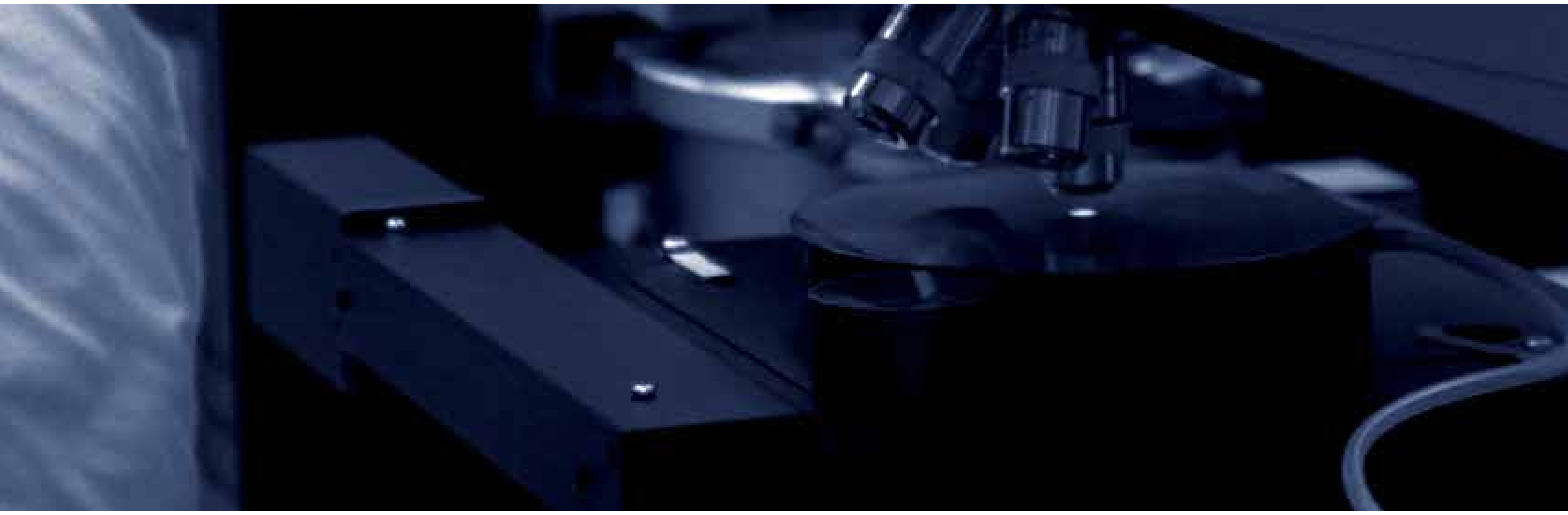
7 THINGS TO KNOW WHEN SELECTING AN IR CAMERA FOR RESEARCH & DEVELOPMENT

A Guide to Investing in Infrared







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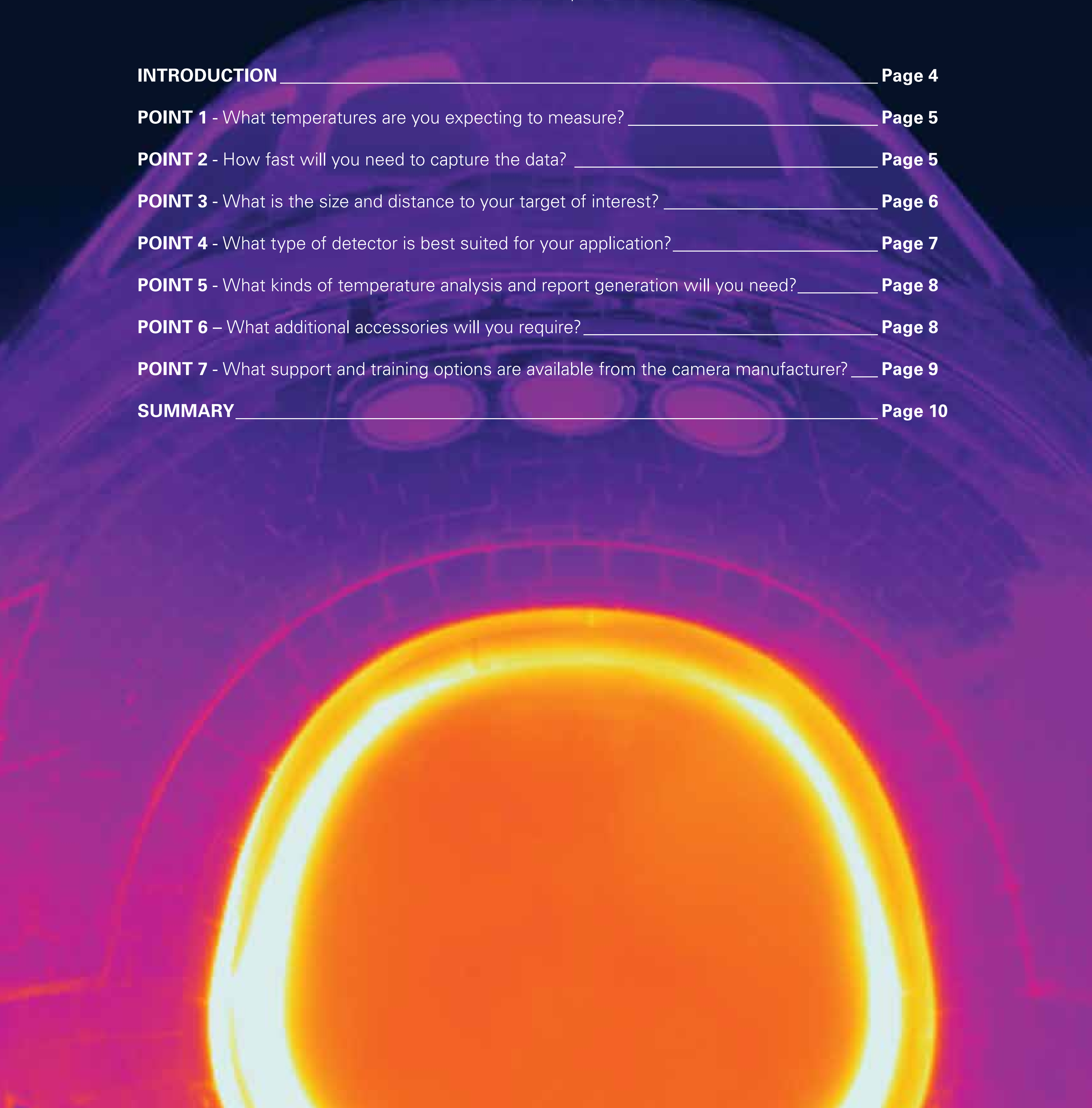

7 THINGS TO KNOW WHEN SELECTING AN IR CAMERA
for Research and Development

To the Reader:

FLIR is dedicated to helping our customers succeed in all their infrared (IR) projects. This booklet was written for that purpose. Back in the mid-1960s, FLIR brought the first commercial infrared camera to market. Now we are the world's largest infrared camera manufacturer, and we operate the world's largest training organization—the Infrared Training Center (ITC). We have condensed a little of that 50 years of experience and knowledge into the "7 Things" contained in this booklet. We trust you will find them useful in selecting the best IR camera for your particular research and development (R&D) projects.

Sincerely,

David C Bursell
VP Business Development FLIR

Introduction

In simple terms, an infrared camera, or "thermal imager" converts infrared radiation into a visual image that depicts temperature variations across an object or scene. This allows one to make non-contact measurements of an object's temperature for data acquisition, analysis, and reporting. The process of using an IR camera for data viewing, recording, analysis, and reporting is called "thermography."

Thermography has become an indispensable tool for all kinds of R&D projects. There are a lot of IR camera options available with different features at varying costs, making it difficult to select a camera best-suited to your application. To ensure you choose one that meets all your requirements, FLIR has put together a list of the seven things you need to know when selecting an IR camera. This list will help you narrow-down your options and point you in the right direction for your ultimate camera selection.

Seven points to consider when selecting an IR camera:

1. What temperatures are you expecting to measure?
2. How fast will you need to capture the data?
3. What is the size and distance to your target of interest?
4. What type of detector is best suited for your application?
5. What kinds of temperature analysis and report generation will you need?
6. What additional accessories will you require?
7. What support and training options are available from the camera manufacturer?

Point #1: What temperatures are you expecting to measure?

Typically, the goal of using an IR camera is to measure temperature changes on your object of interest. Two things you should take into consideration when measuring temperature are: the temperature range of your object and the temperature resolution you wish to achieve. Answering these two questions will help you narrow down which types of infrared cameras and detectors are best suited for your application.

TEMPERATURE RANGE

Temperature range is defined by how cold and hot your object will become. This could also be the coldest and hottest temperature in the scene you are viewing. For example, you may be imaging an aircraft engine idling on the runway. In this example the body of the aircraft may be at an approximate temperature of 25°C and the engine at 500°C. The temperature range would be roughly 25°C to 500°C, so you would look for an IR camera that is capable of measuring the entire range at one time.

TEMPERATURE RESOLUTION

Temperature resolution is the smallest temperature difference you need to measure and is commonly referred to as temperature sensitivity. IR camera sensitivities can range from 0.020°C up to 0.075°C, depending on the camera's detector type.

Temperature resolution or sensitivity for IR cameras is commonly expressed as Noise Equivalent Delta Temperature (NEDT). This figure of merit is the smallest temperature change the IR camera can detect above its noise floor. Simply put, this is the smallest temperature change you can measure with that specific camera. Table 1 shows some common temperature ranges and temperature resolutions of different IR camera types. As you can see there are a lot of options, but defining your temperature range and resolution will help initially narrow down which camera solutions will meet your application requirements.

Note: Temperature resolution (sensitivity) is not the same as the temperature accuracy of the IR camera. Rather, temperature accuracy is the ability of the camera to accurately measure an object's exact temperature. To help explain, imagine we were looking at a hot mug of coffee that is 90°C, but then it quickly cools off to 89°C. It wouldn't be difficult for a camera with good sensitivity to detect that subtle temperature change. But if the camera is miscalibrated, it may read the starting temperature as 91°C and the ending temperature as 90°C; therefore, the camera accuracy is roughly ±1°C.

FLIR Camera Model	Detector Type	Thermal Sensitivity/NEDT	Temp Range
A655sc	Microbolometer	<30 mK	–40°C to 650°C (–40°F to 1202°F) Optional Range: Up to 2000°C
A6751sc MWIR	Indium antimonide (InSb)	<18 mK	–20°C to 350°C (–4°F to 662°F) Optional Range: Up to 1500°C, 2000°C, or 3000°C
X6901sc LWIR	Strained Layer Superlattice (SLS)	<40 mK	–20°C to 650°C (–4°F to 1202°F) Optional Range: Up to 1500°C, 2000°C, or 3000°C

Table 1: Temperature range and resolution of common IR cameras

Point #2: How fast do you need to capture the data?

When answering this question there are three things to consider: exposure time, frame rate, and total record time.

EXPOSURE TIME

Exposure time is how quickly an IR camera can capture a single frame of data, which is similar to shutter speed on a traditional visible-light camera. The exposure time for IR cameras is referred to as integration time, or the detector's thermal time constant. These two terms simply refer to the amount of time it takes to capture a single thermal image.

Let's explore the analogue of the IR camera's exposure time, i.e., a traditional camera's exposure time with respect to the advantages of longer and shorter exposures. For both cameras, the shorter the exposure time, the less likely there will be blurring for high-speed events. However, since the exposure is shorter there is less time for the cameras to image the target; so you may be under-exposed. On the other hand, longer exposure times allow you to collect more light (for the traditional camera) or heat energy (for the IR camera) from your object of interest. The drawback of course is that if your target is moving fast you may see blurring.

So there is a trade-off between short and long exposure times. But if you recall from seeing Table 1, some cameras have better thermal resolution and are therefore more sensitive. We can deduce that it requires less exposure time for the higher-sensitivity cameras to get the same image as the lower-sensitivity cameras when looking at the same thermal target. For cameras that have these better thermal-resolution detectors you get the best of both worlds—good imagery of cooler objects and no motion blur.

To determine if a particular IR camera will meet the speed requirement of your application you will need to consider:

- The motion of your target object.
- How quickly/slowly your target object will heat up or cool down.
- The motion of the IR camera.

FRAME RATE (FRAMES/SECOND)

A camera system's frame rate describes how many thermal images per second you can collect from the IR camera. IR camera systems with fast frame rates allow you to capture the thermal signatures of fast-moving targets, such as ballistic projectiles or explosion scenes. If data acquisition is fast enough, it's even possible to capture a sequence and play it back in slow motion. So, the higher the camera's frame rate, the better the results for dynamically changing targets.

As you would imagine, shorter exposure times allow for faster frame rates. Thermal cameras have frame rates that vary from a few frames per second to thousands of frames per second. Here is Table 1 again with an added column showing frame rates and exposure times:

FLIR Camera Model	Detector Type	Exposure Times	Frame Rate
A655sc	Microbolometer	12 milliseconds	50 Hz
A6751sc MWIR	Indium antimonide	1.0 milliseconds	125 Hz
X6901sc LWIR	Strained Layer Superlattice (SLS)	0.2 milliseconds	1000 Hz

Table 2: Frame rates and exposure times of common IR cameras

TOTAL RECORD TIME

Do you plan on capturing data at high speed for long periods, high speed for short bursts of data, or data log at slow rates for hours? There are as many data recording options as there are cameras, so all data-collection scenarios should be explored to determine the type of IR recording system you will need.

It is important to know the frame rate and total record time you require to select a camera and data system that will work best for your application. Certain IR cameras, such as FLIR's handheld T-series, have built-in storage capabilities where they can record to internal flash memory or a removable compact SD card. Other cameras, such as the FLIR X6900sc, stream high-speed thermal data over Gigabit Ethernet, CameraLink, or CoaxPress to a PC or laptop for recording. FLIR's high-speed X-Series cameras give you the capability to perform burst recording to on-camera RAM with direct playback and data storage to a removable solid-state drive (SSD). For high-speed, extended-length recording there are solutions where data is streamed to a RAID array of disks that can handle fast frame rates and feature large amounts of disk space. If data security is a concern, the storage media is removable on both the camera and high-speed data recorder. Simply take it out and store it in a safe place.

Point #3: What is the size and distance to your target of interest?

To get the best thermal imagery and most points of measurement on your thermal object of interest, you should select a lens that fills the field of view with the target of interest. At the same time, you typically want to optimize your spatial resolution to make sure the smallest object detail you need to see matches your instantaneous field of view.

SPATIAL RESOLUTION

Spatial resolution is the same as instantaneous field of view (IFOV). Both are the smallest physical detail you can detect on your target and are based on the smallest area a single camera (detector) pixel covers. The closer you are to an object, the smaller the area a pixel will detect. As you move farther away, the single pixel covers a larger area of interest (see Figure 1).

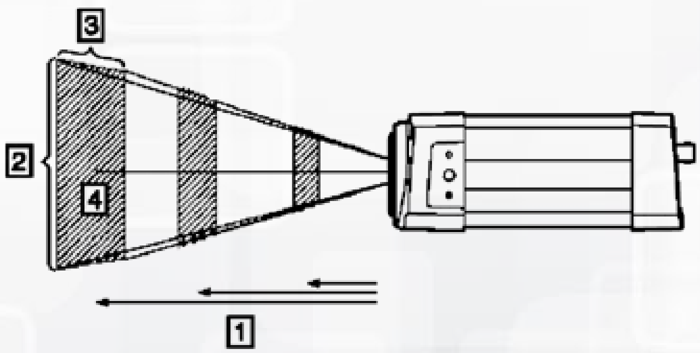

Figure 1: Field of view and instantaneous field of view

FIELD OF VIEW (FOV)

As you'll notice, the field of view also changes as you view objects from farther away. Similar to spatial resolution, this means you will have fewer pixels on a target when imaging from a distance than you will from close-up. Ideally you want the object to fill the field of view, but sometimes this is not possible due to the heat of the target and the danger it could pose for the camera or the operator.

Once you have defined the desired field of view and spatial resolution you can select the best lens or set of lenses for your application. The math required to determine these values by hand can be daunting, so FLIR has developed a free online field of view calculator to assist you with this process (www.flir.com/custhelp/calculator). To use the online tool, simply enter the object size, distance to the object, and prospective lens. The calculator will compute the field of view, spatial resolution, and number of pixels on the object of interest—making the lens selection process very easy.

Point #4: What type of detector is best suited for your application?

In Point 1 of this guide, we explained how temperature measurement sensitivity varies based on the IR camera's detector type. An additional point to consider is that different detector technologies sense infrared energy in different wavelengths or wavebands. Depending on your application, the waveband over which the IR camera senses energy can have a significant impact on measurement results.

If you look at Figure 2, you'll see a typical atmospheric IR transmission curve. According to the figure, there is good IR transmission through the atmosphere at 7.5 µm to 13.0 µm and 3.0 µm to 5.0 µm. Thus, if your application requires you to look long distances through the atmosphere, then choosing detectors that operate in these transmission windows is optimal.

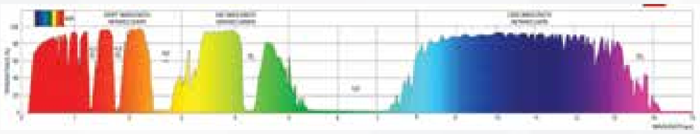

Figure 2: Atmospheric transmission for infrared energy

Similar thinking applies to other applications that involve looking at or through materials. For example, what if you want to measure the temperature of the filament of a lightbulb? To do this you would need to look through the bulb's outside layer of glass. Looking at the transmission curve for the bulb's glass (Figure 3), you see a spectral window that allows for the transmission of IR. To see through the glass and measure the filament will require a camera that senses in the 3.0 µm to 4.1 µm waveband.

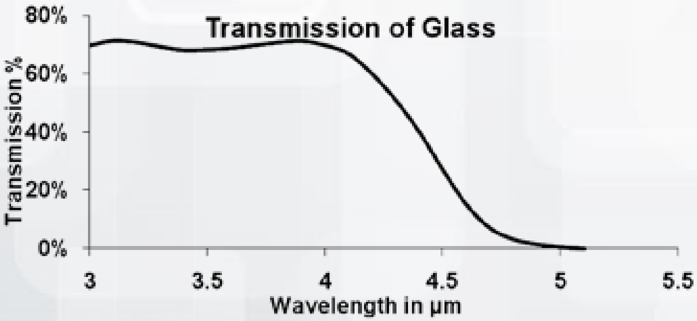

Figure 3: Transmission curve of light bulb glass example

Figure 4 illustrates what happens when you look at a light bulb with a camera that senses within the glass transmission window. Thanks to the camera's 3.0 – 5.0 µm InSb detector, you would be able to precisely measure the temperature of a light bulb filament.

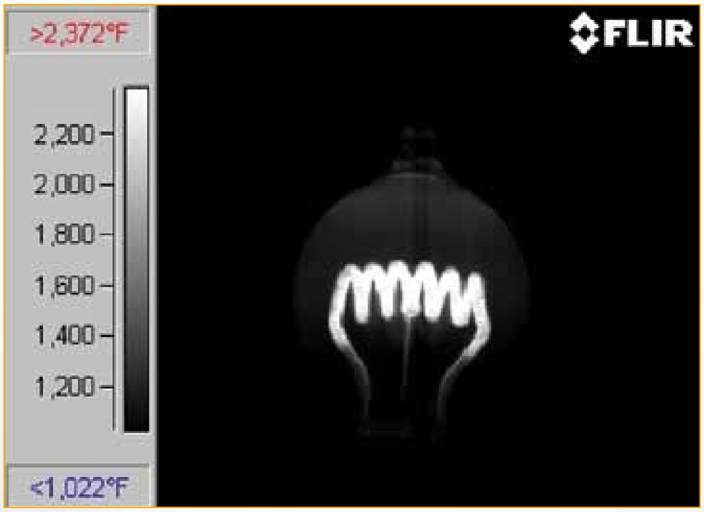

Figure 4: Thermographic image of light bulb with InSb detector (3.0 µm to 5.0 µm) and < 4.1 µm filter

Figure 5 on the other hand, illustrates what happens when you look at a light bulb with a camera that operates outside the glass transmission window. Attempting to measure the filament using a 7.5 – 13.0 µm microbolometer camera results in temperature measurements from the glass surface of the bulb, instead.

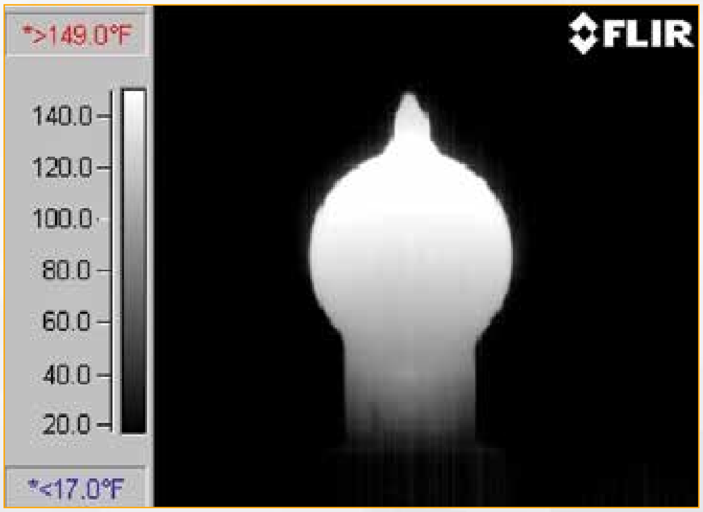

Figure 5: Thermographic image of light bulb with microbolometer detector (7.5 µm to 13.0 µm)

To summarize, for certain applications, looking through materials may guide you to a specific detector based on its unique spectral waveband response.

Point #5:
What kinds of temperature analysis and report generation are needed?

Up to this point, we have focused primarily on considerations for the infrared camera hardware and data collection, but this is really only half of a system solution. The other half is data analysis and report generation (data sharing). In this section we focus on defining what data analysis is required for certain applications and what methods are available to share data with colleagues and customers.

DATA ANALYSIS

FLIR's temperature-calibrated IR cameras provide a temperature value for each pixel in degrees Kelvin, Fahrenheit, and Celsius. Displaying the image is a great way to quickly see where your target is very hot or cold. Still, techniques for image enhancement, image subtraction, emissivity adjustment, and plotting of charts and graphs can prove even more useful, helping someone really understand the thermal changes taking place on a target object.

The most basic tool used in thermography is image enhancement to adjust the level and span of the image color palette. This allows you to enhance the image and draw out the subtle temperature differences. Additionally, software that allows for the subtraction of a baseline image from the energized image allows you to remove any reflected ambient temperatures and expose extremely small temperature variances. This technique is critical for objects that are reflective or have a low emissivity.

Other important tools allow the plotting of data in charts or graphs. Examples include: histograms, line profile graphs, and temperature vs. time charts. These graphs and charts help you characterize target heat distribution and temperature changes over time. Figure 6 shows examples of all these analysis tools.

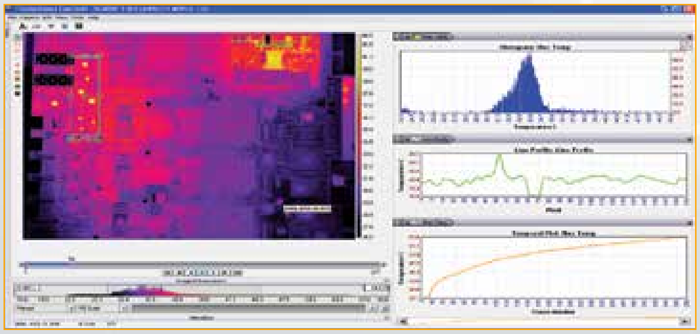

Figure 6: Example data analysis software tools report generation

At some point in an R&D project, the data collected and analyzed will be shared with others. For example, you may want to share raw data with colleagues for additional analysis or share analysis results with customers. As such, it is critical to know who you will be sharing data with and the format they require in order to effectively use your results.

In many instances, custom data analysis with third-party software such as MatLab or Excel is desired. Having an IR software package that allows data export in, for example, a .CSV file is ideal for use in Excel or Matlab. Similarly, data collected over a long period of time is best shared as a data-log file where data is exported in a text file or spreadsheet file-format. Again, this is ideal for importing into third-party software solutions for further analysis.

For management and customers, static images or movie files that can be inserted into emails, slide presentations, or word processor documents will best illustrate IR analysis results. So the ability to export IR sequences and images as .JPG or .BMP files for static imagery and export movies as .AVI or .WMV is a must.

SUPERFRAMING

Superframing involves cycling the IR camera through up to four unique temperature ranges and sequentially capturing data from each range. Software, such as FLIR ResearchIR, can then present this data as separate movie files (one movie file for each temperature range), or combine the movie files into a single extended temperature range superframe movie. Superframing only works with certain cameras and software. Refer to FLIR's "The Ultimate Infrared Handbook for R&D Professionals," available at **www.flir.com/science-guidebook** for more information on superframing.

Point #6:
What additional accessories may be required?

Project equipment requirements may extend beyond the need for an infrared camera and software. For example, you may need a protective enclosure to use your camera in a harsh or demanding environment. Safety requirements may force you to work miles away from the camera, necessitating a remote operation system. In these and other situations, it's vital to buy from an IR camera provider that can offer accessories as turn-key solutions.

For mounting the camera outdoors or in manufacturing environments, you may want to consider an enclosure with a special infrared window that is optimized for that specific camera and detector. Another consideration is: will the camera be looking inside an environmental chamber or other pressurized enclosure where a special infrared window would be required? In either of these scenarios, you need to make sure you get a window that has good transmission for the detector's waveband of sensitivity and has anti-reflective coatings. FLIR provides tools for calculating what type, size, and thickness of material will be best suited for your requirements. FLIR also offers off-the-shelf enclosures for most cameras, creating a true out-of-the-box solution. (See Figure 7.)

Figure 7: FLIR RS8300 environmental enclosure example

Another common accessory is a cable extension for situations where the camera is located a long distance from the camera operator. One example is if the camera is on a tracking mount near a test that is considered too dangerous for humans. In this case you can use Ethernet, Firewire, or CameraLink to fiberoptic extenders that allow you to transmit the thermal data at full frame rates for miles if necessary. FLIR provides solutions for these situations as well, which save you time and money and removes the guess work in building an integrated test system.

There are many additional considerations for optional accessories when building the final thermography system. Be sure to consider the test environment when defining your infrared system requirements, and take note of what accessories may be helpful. Whether it is availability of the appropriate optics, extended cable lengths, a camera stand, enclosure, or a data system, FLIR is dedicated to helping you solve these problems with a broad range of products, and information on third-party sources.

Various accessories are available to customize your FLIR camera

Point #7: What support and training options are available from the camera manufacturer?

This is frequently overlooked when setting out to buy an IR camera. As is true with other sophisticated instruments, IR cameras provide a wide range of capabilities. Application and other factory support becomes very important in getting the most out of your camera system investment. Support might be as routine as supplying delivery details on an order, or as complex as describing temperature measurement techniques on reflective targets. FLIR is always there when things don't go as planned, when repairs are required, and when training sessions are needed.

For example, our education and training capabilities include:

- Organized training available in the form of classes—formalized training of camera usage, software, and data collection systems; application techniques; physics of radiometry and thermography.
- Training at the manufacture facility—you're able to interface with those who engineer, build, and service camera systems.
- Regional training—nearby to reduce travel.
- Customer site training—provided at the customer site location for application-specific training.

Individualized learning with your own camera

itc INFRARED TRAINING CENTER

In addition, customers who purchase directly from FLIR benefit from:

- Access to engineers who are thermography experts.
- Direct flow of information—upgrades, new releases, education, etc.
- Dedication and focus—FLIR focuses on one thing: infrared imaging and measurement.

Engineers and experts are available to help you maintain your FLIR camera

SUMMARY

The tips presented in this booklet covers the major criteria to consider when selecting an IR camera for R&D applications. We hope you found it both informative and helpful in narrowing down which IR camera solutions are best suited for your unique application. More detailed information on these topics can be found in FLIR's infrared camera R&D handbook, available at: www.flir.com/science-guidebook.

While we hope you choose to buy a FLIR infrared camera, we realize there are many choices available. When researching all the options, you may find that specifications for other cameras you're considering are incomplete or confusing, which makes selection more difficult. If you have questions, give us a call. We can answer many of your questions on the phone. Better still, we can arrange a personal product demonstration to give you hands-on experience in how a camera works in a real application.

For more information please send an email to **research@flir.com** or visit **www.flir.com/science.**

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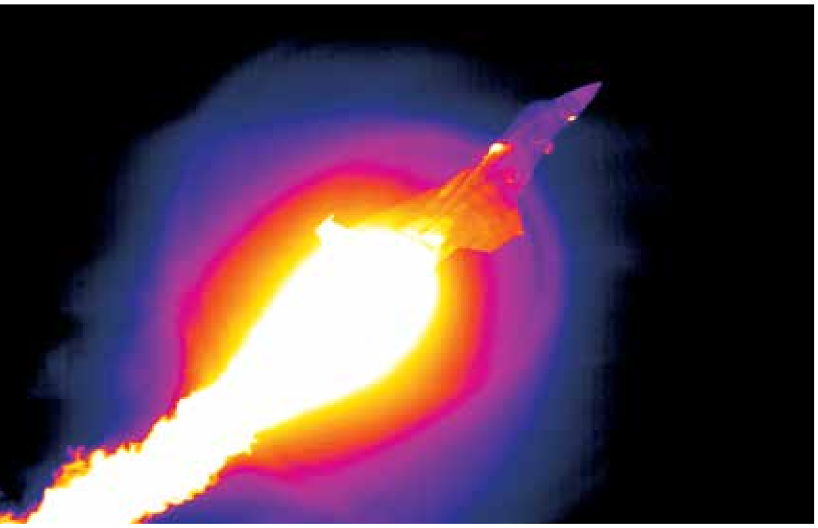

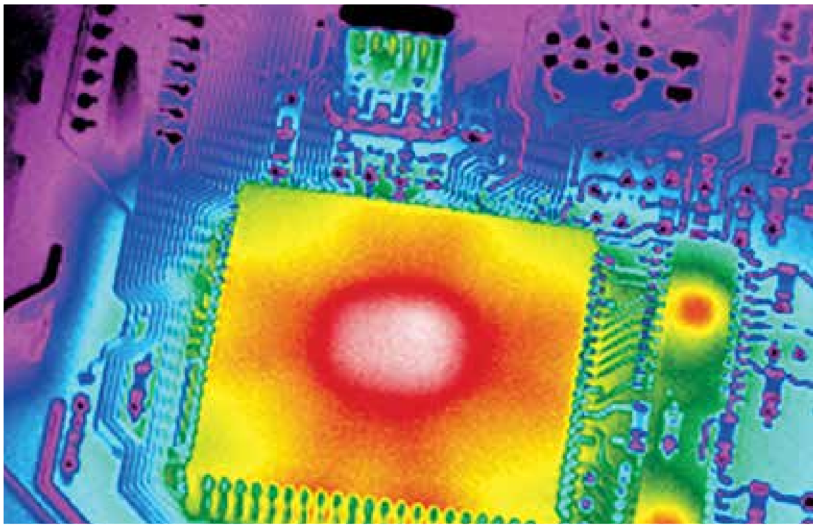

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