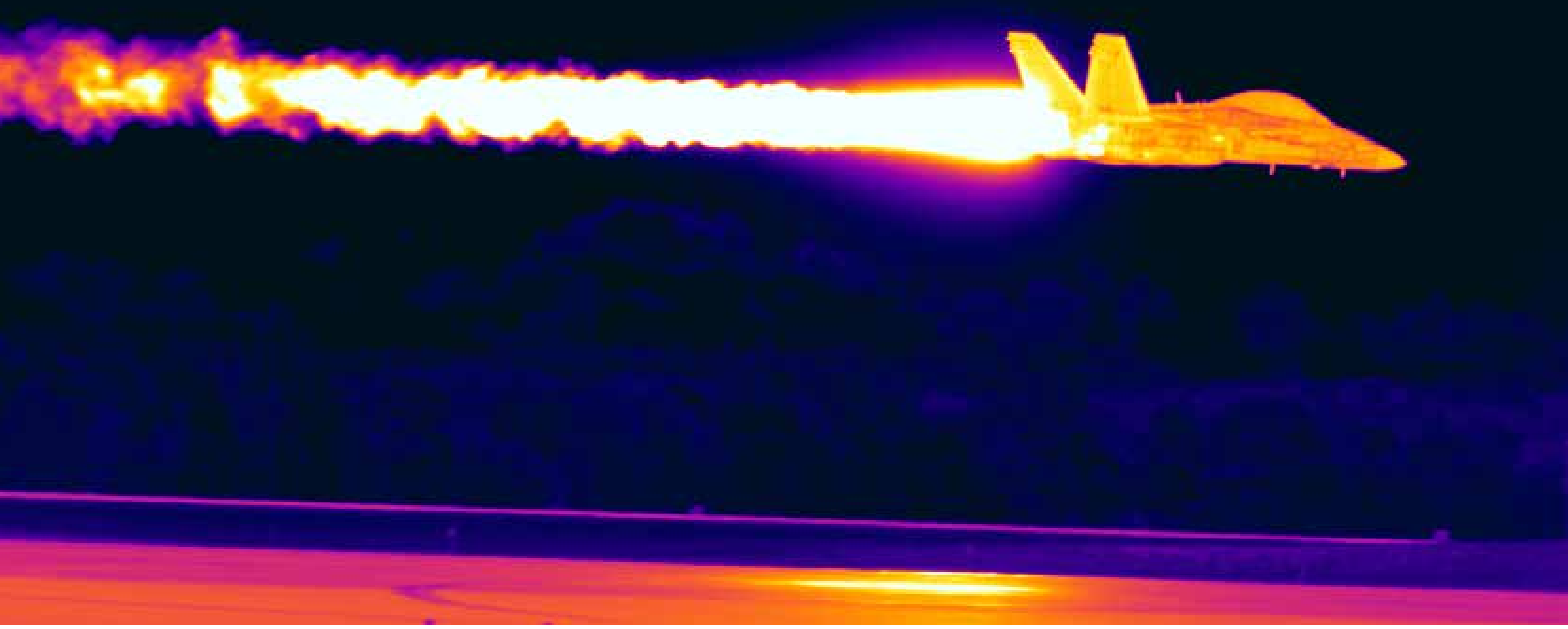
TECHNICAL NOTE



# COOLED VS UNCOOLED THERMAL IMAGING

## Discover the difference

*For many years, thermal imaging cameras have been used by scientists, researchers and R&D specialists for a wide range of applications, including industrial R&D, academics & research, non-destructive testing (NDT) & materials testing, and defense and aerospace. However, not all thermal cameras are created equal and for some applications dedicated, advanced thermal cameras with high speed stop motion capability are required in order to get accurate measurements.*

Thermal imaging cameras for Science / R&D applications are powerful and non-invasive tools. With a thermal imaging camera you can identify problems early in the design cycle, allowing them to be documented and corrected before becoming more serious and more costly to repair.

### THERMAL IMAGING IN AN R&D ENVIRONMENT

Thermal imaging cameras use thermal radiation, which is not detectable by the human eye, but can be converted into a visual image that depicts thermal variations across an object or scene. Covering a part of the electromagnetic spectrum, thermal energy is emitted by all objects at temperatures above absolute zero, and the amount of radiation increases with temperature.

FLIR's thermal imaging cameras are used for capturing and recording thermal distribution and variations in real-time, allowing engineers and researchers to see and accurately measure heat patterns, dissipation, leakage, and other temperature factors in equipment, products and processes. Some of these cameras can distinguish temperature changes as subtle as 0.02°C. They feature state-of-the-art detector technology and advanced mathematical algorithms for high performance and precise measurements from -80°C to +3000°C. The R&D camera ranges combine extremely high imaging performance and precise temperature measurements, with powerful tools and software for analyzing and reporting. This combination makes them ideal for a wide range of research, thermal testing and product validation applications.

*Thermal imaging cameras with a cooled detector can produce crisp thermal images of fast moving events.*


*The FLIR A6700sc is a compact, thermal imaging camera with cooled InSb detector at an extremely affordable price.*

*The FLIR T650sc uncooled research camera has high resolution, with small spot size for precise results, and reliable temperature measurement accuracy.*

### COOLED AND UNCOOLED CAMERAS

There is plenty of choice when it comes to thermal imaging camera systems for R&D/science applications. An often asked question is therefore: "Should I use a cooled or an uncooled thermal imaging system and which one is the most cost effective?" In fact, there are two classes of thermal imaging camera systems available on the market today: cooled and uncooled systems. The component costs for these two classes of systems can be quite different, making it extremely important to decide which way to go.

## COOLED THERMAL IMAGING CAMERAS

A modern cooled thermal imaging camera has an imaging sensor that is integrated with a cryocooler.

This is a device that lowers the sensor temperature to cryogenic temperatures. This reduction in sensor temperature is necessary to reduce thermally-induced noise to a level below that of the signal from the scene being imaged. Cryocoolers have moving parts made to extremely close mechanical tolerances that wear out over time, as well as helium gas that slowly works its way past gas seals.

Cooled thermal imaging cameras are the most sensitive type of cameras and can detect the smallest of temperature differences between objects. They can be produced to image in the mid-wave infrared (MWIR) band and the long-wave infrared (LWIR) band of the spectrum where the thermal contrast is high due to blackbody physics. Thermal contrast is the change in signal for a change in target temperature. The higher the thermal contrast, the easier it is to detect objects against a background that may not be much colder or hotter than the object.

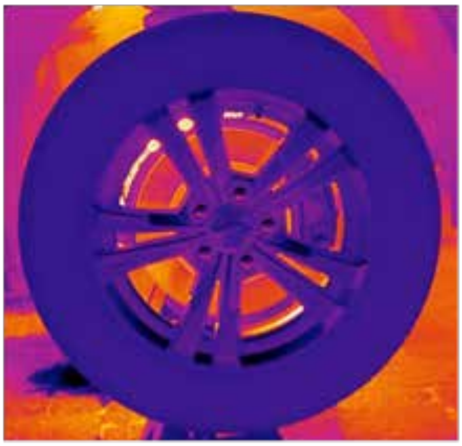
## UNCOOLED THERMAL IMAGING CAMERAS

An uncooled infrared camera is one in which the imaging sensor does not require cryogenic cooling. A common detector design is based on the microbolometer, a tiny vanadium oxide resistor with a large temperature coefficient on a silicon element with large surface area, low heat capacity and good thermal isolation. Changes in scene temperature cause changes in the bolometer temperature which are converted to electrical signals and processed into an image. Uncooled sensors are designed to work in the Longwave infrared (LWIR) band, where terrestrial temperature targets emit most of their infrared energy. Uncooled cameras are generally much less expensive than cooled infrared cameras. The sensors can be manufactured in fewer steps with higher yields relative to cooled sensors, less expensive vacuum packaging, and uncooled cameras do not require cryocoolers, which are very costly devices. Uncooled cameras have fewer moving parts and tend to have much longer service lives than cooled cameras under similar operating conditions.

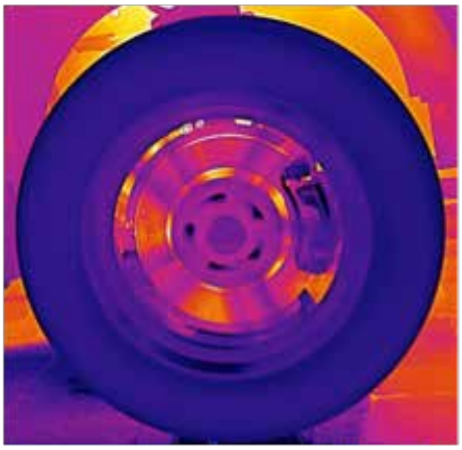
## COOLED CAMERAS FOR R&D APPLICATIONS

Advantages of uncooled cameras beg the question: When is it better to use cooled thermal imaging cameras for R&D/ science applications? The answer is: it depends on the application requirements.

*Figure 1*



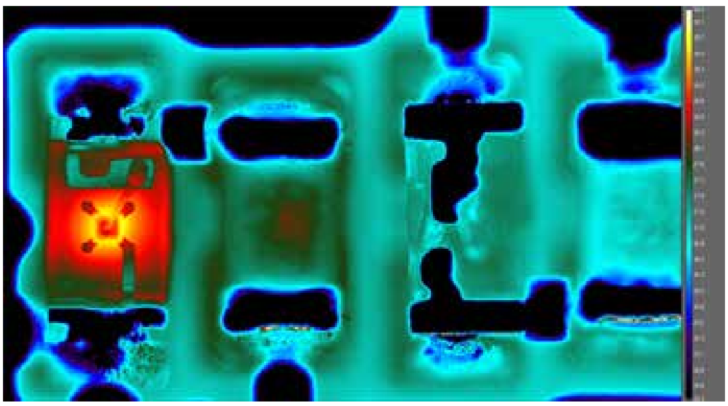
*Cooled thermal Camera Image of Rotating Tire*



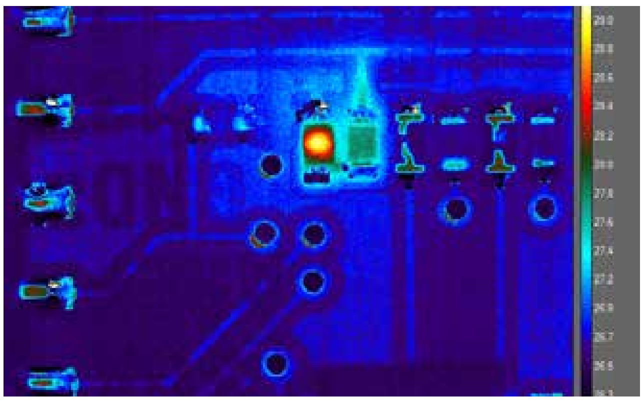
*Uncooled Thermal Camera Image of Rotating Tire*

If you want to see the minute temperature differences, need the best image quality, have fast moving or heating targets, if you need to see the thermal profile or measure the temperature of a very small target, if you want to visualize thermal objects in a very specific part of the electromagnetic spectrum, or if you want to synchronize your thermal imaging camera with other measuring devices, then a cooled thermal imaging camera is the instrument of choice.

*Figure 2*



*Cooled thermal camera image of electronics board*



*Uncooled thermal camera image of electronics board*

## SPEED

Cooled cameras have much higher imaging speeds than uncooled ones. High-speed thermal imaging allows microsecond exposure times that stop the apparent motion of dynamic scenes and permit capturing frame rates exceeding 62,000 frames per second. Applications include thermal and dynamic analysis of jet engine turbine blades, automotive tire or airbag inspection, supersonic projectiles, and explosions to name a few.

Cooled cameras have very fast response times and they make use of a global shutter. This means that they will read out all pixels at the same time, as opposed to reading them out line by line, which is the case with uncooled cameras. This allows cooled cameras to capture images and take measurements on moving objects without image blurring.

The IR images in Figure 1 compare the capture results of a tire rotating at 20mph. The upper image was taken with a cooled thermal imaging camera. One would think the tire is not spinning, but this is the result of a very fast capture rate of the cooled camera that has stopped the motion of the tire. The uncooled camera capture rate is simply too slow to capture the rotating tire causing the wheel spokes to appear transparent and blurred (see lower image). You cannot accurately measure temperature on blurred images.

## SPATIAL RESOLUTION

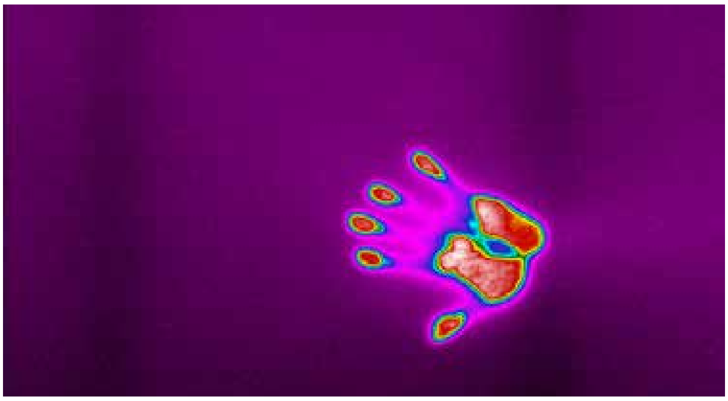
Cooled cameras typically have greater magnification capabilities than uncooled cameras, because they sense shorter infrared wavelengths. Because cooled cameras have greater sensitivity characteristics, lenses with more optical elements or thicker elements can be used without degrading the signal to noise ratio, allowing for better magnification performance.

The thermal images in Figure 2 compare the best close-up magnification that can be achieved with a cooled and uncooled camera system. The image on the left was taken with a 4× close-up lens and 15µm pitch cooled camera combination resulting in a 3.5µm spot size. The image on the right was taken with a 1× close-up lens and 25µm pitch uncooled sensor resulting in a 25µm spot size.

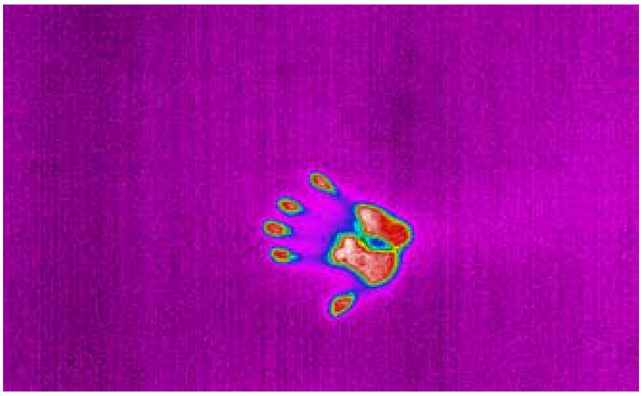
## SENSITIVITY

It is often difficult to fully appreciate the value offered by the improved sensitivity of cooled thermal cameras. How do you get a feeling of the benefit from a 50mK sensitivity uncooled thermal camera in comparison to a 20mK sensitivity cooled thermal camera? To help illustrate this benefit we ran a quick sensitivity experiment (See Figure 3). For this comparison we put our hand on a wall for a brief few seconds to create a thermal handprint. The first two images show the handprint immediately

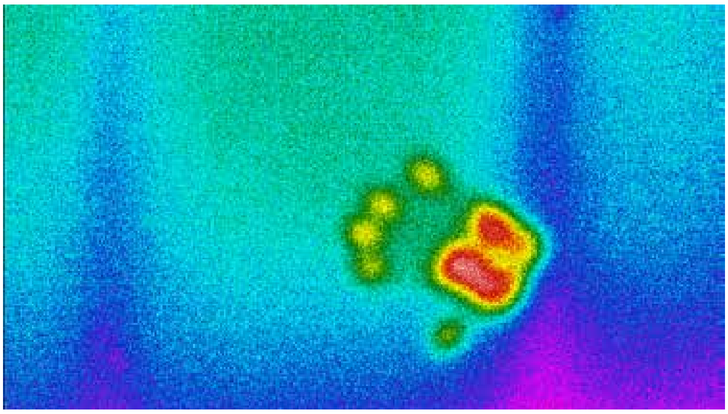
*Figure 3*



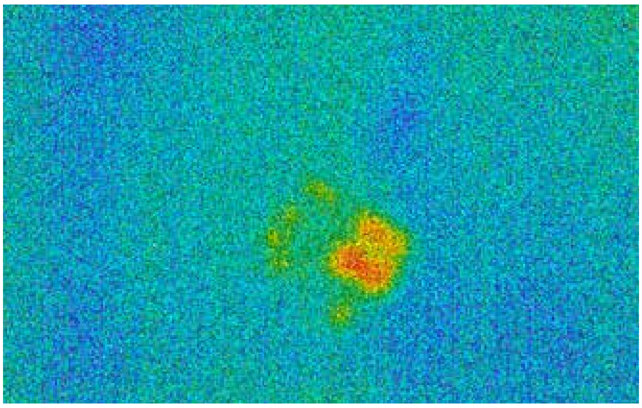
*Cooled thermal camera image of handprint on wall initial image*



*Uncooled thermal camera image of handprint on wall initial image*

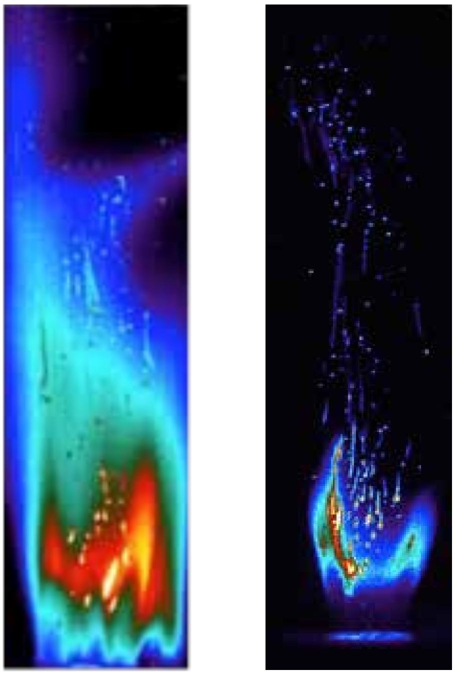


*Cooled thermal camera image of handprint on wall after 2 minutes*



*Uncooled thermal camera image of handprint on wall after 2 minutes*

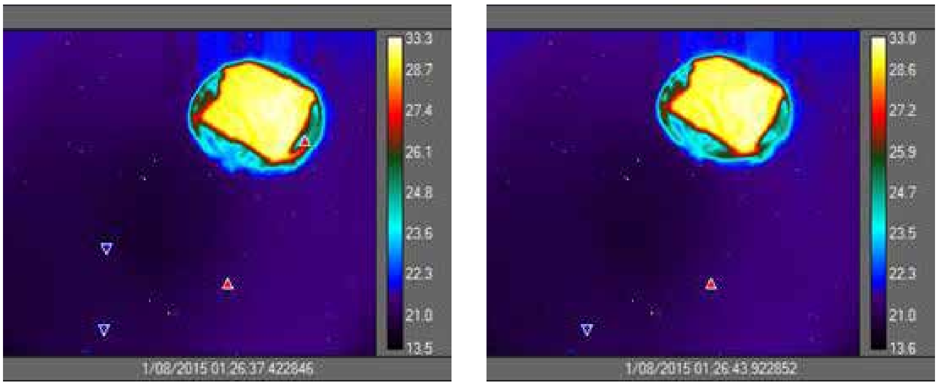
*Figure 4*



*Cooled Thermal Image without Spectral Flame Filter*

*Cooled Thermal Image with Spectral Flame Filter*

*Figure 5*




*Two drops of the same coin will trigger the camera at the same time giving you the object in the same position every time.*

after the hand was removed. And the second set of images shows the thermal handprint's signature after two minutes. The cooled camera can still see most of the thermal signature of the handprint, whereas the uncooled cameras only show the partial remains of the handprint. The cooled camera clearly can detect smaller temperature differences and for longer durations than the uncooled camera. This means the cooled camera will provide better detail on your target and help you detect even the faintest of thermal anomalies.

## SPECTRAL FILTERING

One of the great advantages of cooled thermal cameras is the ability to easily perform spectral filtering in order to uncover details and take measurements that otherwise would be unachievable with uncooled thermal cameras. In the first example shown in Figure 4, we are using a spectral filter, either placed in a filter holder behind the lens or built into the dewar detector assembly, in order to image through flame. The end user wanted to measure and characterize the combustion of coal particles within a flame. Using a "see through flame" spectral infrared filter, we filtered the cooled camera to a spectral waveband where the flame was transmissive and therefore we were able to image the coal particle combustion. The first image is without the flame filter and all we see is the flame itself. The second is with the flame filter and we can clearly see the combustion of coal particles.

## SYNCHRONIZATION

Precise camera synchronization and triggering makes the cameras ideal for high-speed, high sensitivity applications. Working in snapshot mode the FLIR A6750sc is able to register all pixels from a thermal event simultaneously. This is particularly important when monitoring fast moving objects where a standard uncooled thermal infrared camera would suffer from image blur.

The images in Figure 5 are a good example. In this example, we dropped a coin and had a sensor trigger the camera to take an image. Two drops of the same coin triggered the camera at the same time, giving you the object in the same position each time as well. With an uncooled microbolometer camera, you would not catch the coin at all due to the inability to trigger that type of detector and if you did by luck it would be blurred.

## THERMAL CAMERAS FROM FLIR

The higher performance A6750sc, A8300sc, SC6000, SC7000, SC8000, X6000sc, and X8000sc cooled cameras offer ultra-fast, ultra-sensitive performance in the MWIR and LWIR spectral bands, while the FLIR A6250sc operates in the NIR spectral band. These cameras provide superior measurement capabilities in challenging setups for fast motion and thermal events, wide temperature range, small amplitude phenomena, multispectral analysis or very small object evaluation.

FLIR also offers a wide range of uncooled cameras, from entry-level bench test kits up to higher end systems like the FLIR T650sc. Dedicated lenses and software will adapt your camera solution to your specific application. To know exactly which cooled or uncooled camera you need, please contact your FLIR representative.

For more information about thermal imaging cameras or about this application, please visit:

**www.flir.com**