



eDrone

Educational for Drone (eDrone)
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Educational for Drone (eDrone) **INFRARED**

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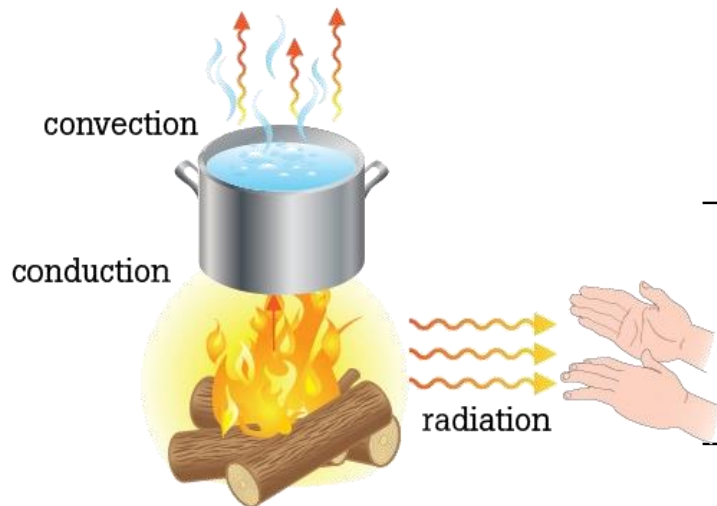
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**Didactic Module
2-8 July 2018**

How heat transfer relates to thermal imaging

- Heat energy can be transferred in three basic ways: conduction, convection and radiation. Thermal imagers, or infrared cameras, can only detect radiated heat energy, so it's important to understand the distinction so you know the limitations of your thermal imaging device.



- **Conduction** is the transfer of thermal energy from one object to another through direct contact. Heat transfer by conduction occurs primarily in solids, and to some extent in fluids, as warmer molecules transfer their energy directly to cooler, adjacent ones. For example, you experience conduction when touching a warm mug of coffee or a cold soft drink can.
 - **Convection** is the transfer of heat that occurs when molecules move and/or currents circulate between the warm and cool regions of air, gas, or fluid. Convection occurs in both liquids and gases, and involves the mass movement of molecules at different temperatures. For example, a thundercloud is convection that occurs on a large scale because as masses of warm air rise, cool air sinks.
 - **Radiation** is the transfer of heat energy that occurs by electromagnetic waves, which is similar to light transmission. An example of radiation is feeling the heat of the sun.

- All objects radiate electromagnetic energy at the speed of light. Electromagnetic energy is radiated in waves with electric and magnetic properties. It can take on several forms including light, radio waves, and infrared radiation. The primary difference among all of the wave types is their wavelength. Normal eyesight detects visible light wavelengths, while infrared cameras detect radiated heat (or infrared radiation) wavelengths.



Planck's law

Planck's law describes the spectral density of electromagnetic radiation emitted by a black body in thermal equilibrium at a given temperature T .

The spectral radiance of a body, B_ν , describes the amount of energy it gives off as radiation of different frequencies.

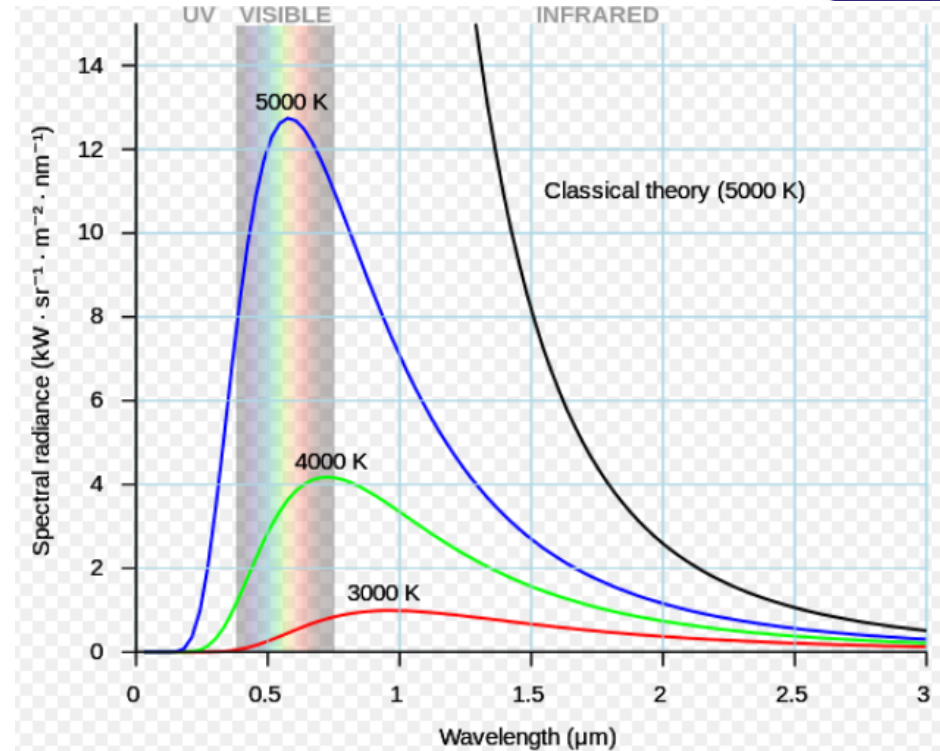
It is measured in terms of the power emitted per unit area of the body, per unit solid angle that the radiation is measured over, per unit frequency.

Planck showed that the spectral radiance of a body for frequency ν at absolute temperature T is given by

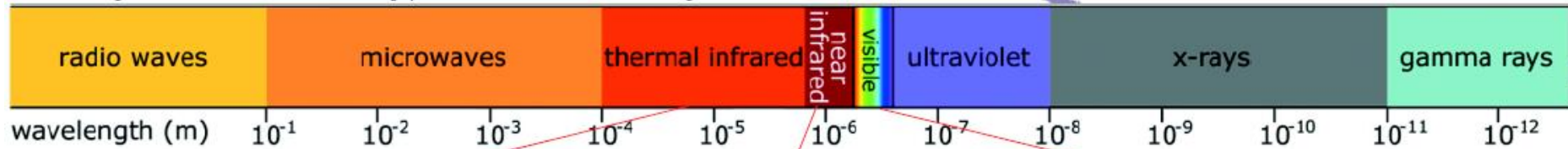
$$B_\nu(\nu, T) = \frac{2h\nu^3}{c^2} \frac{1}{e^{\frac{h\nu}{k_B T}} - 1}$$

where k_B is the Boltzmann constant, h is the Planck constant, and c is the speed of light in the medium, whether material or vacuum.^{[1][2][3]} The spectral radiance can also be measured per unit wavelength λ instead of per unit frequency. In this case, it is given by

$$B_\lambda(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}$$



Infrared



Thermal Infrared



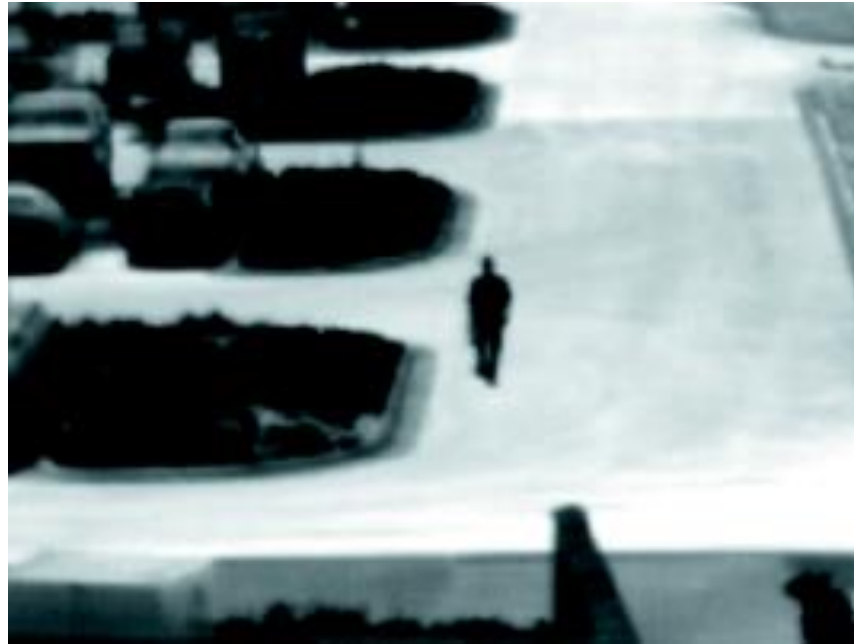
Near Infrared



Visible



Thermal Infrared



- This thermal infrared image shows a person walking across asphalt on a hot afternoon. The person's body is cooler than the hot asphalt, so it appears black while the asphalt appears white. The concrete and vegetation of the parking medians also are darker than the asphalt because they absorb and emit less radiation.

Near Infrared



- This near infrared image shows a strong contrast between the clouds and sky because clouds scatter much more infrared radiation than do air molecules, which scatter mostly blue light. The rocks and conifer trees reflect little near-infrared light, while the foreground vegetation reflects much more.

Visible



- This visible image shows a full-color representation of the world, just
- how your eyes see it. Scattering creates the appearance of a blue sky,
- white or gray clouds, green vegetation, and red-orange sandstone rocks.

What is Infrared



Introduction to Thermal imaging

- Thermal imaging is the technique of using the heat given off by an object to produce an image of it or to locate it
- First developed for military purposes in the late 1950s and 1960s by Texas Instruments, Hughes Aircraft and Honeywell
- In recent times it is being used in firefighting, law enforcement, industrial applications, security, transportation, medical and many other industries

THERMAL IMAGING

- It is the technique of using the heat given off by an object to produce an image of it .
- Works in environments without any ambient light and can penetrate obscurants such as smoke, fog and haze.
- Normally grey scale in nature: black objects are cold, white objects are hot and the depth of grey indicates variations between the two .
- Some thermal cameras, however, add color to images to help users identify objects at different temperatures



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- An image generated from a Thermal Imaging Camera. Note the persons skin (as a heat source) is shown as 'white hot' whilst the sky (which is cold) is shown as black.

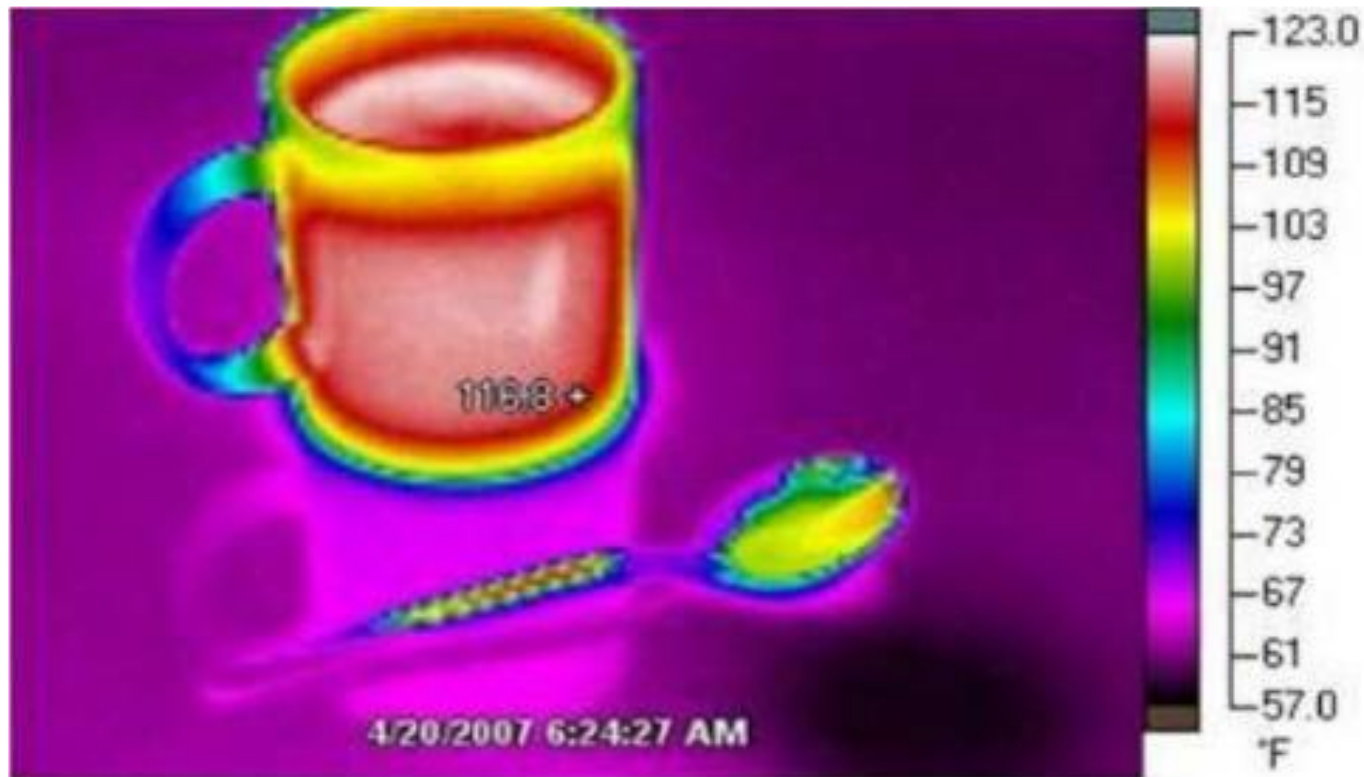




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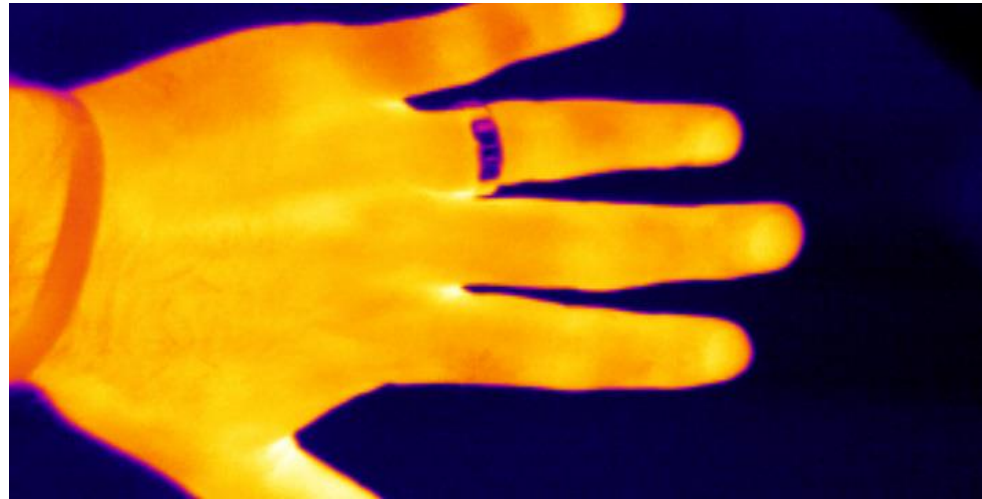
- Cup Filled With Hot Water



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An experiment



- If you use your thermal imager to view a hand with a ring on it, you will see a difference in the thermal image. The ring appears to be much colder than the hand, yet the ring is actually at a similar temperature to the hand. Therefore, although the two objects are at the same temperature, they are radiating different amounts of infrared energy.

Emissivity: Understanding How it Affects Your Thermal Images

- Emissivity (ϵ) is the ratio of how well a material radiates infrared energy, compared to a perfect radiator. Emissivity values fall between 0.0 and 1.0. An object that measures 1.0 is considered a perfect radiator and is called a “black body”.
- **Emissivity describes how to quantify the efficiency of a surface for radiating energy in a defined waveband and at a given temperature.** Reality says any surface above absolute zero will always radiate some energy (more than 0%), and no surface can radiate perfectly (100%).
- When considering infrared radiation most shiny metals emit inefficiently. This means they don't tell us the thermal truth about themselves! Most non-metal surfaces—paint, paper and human skin, for example—are much more efficient emitters, so it is easy to make a direct connection between what they radiate and their surface temperature.



Emissivity variation range

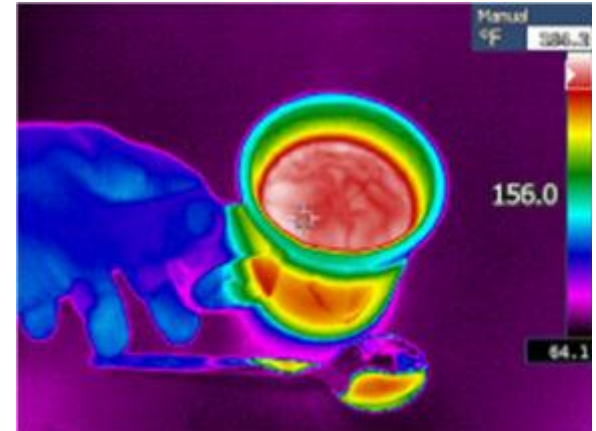
- Emissivity values can be determined or measured by engineers. Be aware, however, they are *very* specific to the material type, surface condition and, especially for metals, the temperature of the material. We can use the values not only to help us understand how a surface might behave but also, in some cases, to correct our radiometric measurements
- Thinking of these values as percentages may help.
- Human skin, with a value of 0.98, is 98% efficient at emitting thermal radiation
- Shiny aluminum, with a value of approximately 0.10, emits only 10% of the energy.
- When we input these values into our imagers, they automatically correct the raw data that had assumed 100% radiation was emitted based on the surface temperature.

Emissivity tips and tricks

- As you can imagine measurements using extreme corrections, as are necessary for bare metals, often are unreliable and that is why we strongly recommend making measurements only on surfaces with **values greater than approximately 0.6**.
- **Solution:** On metals, the simplest way is to add a high-emissivity “target” of paint or electrical tape.

Setting Emissivity

- When you input a correction, the resulting changes are made to the *entire* image.
- Because of this fact, separate corrections must be made for each different point we want to measure.
- While some thermocamera models allow these corrections to be made in the imager itself, the good news is they can also be made in the software to a stored image.
- All changes can be undone or “tweaked” to better match reality.



A single image often contains many surfaces each with a different emissivity and different temperatures.



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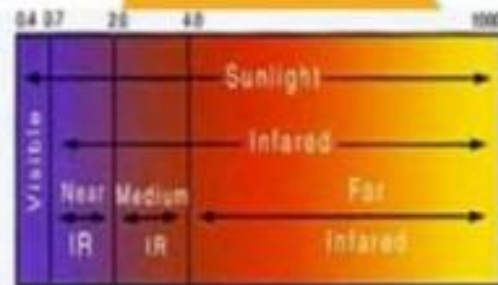


THERMAL IMAGING CAMERA (TIC)

A thermal imaging camera records the intensity of radiation in the infrared part of the electromagnetic spectrum and converts it to a visible image.



IR Band	Wavelength Range
IR-A	700nm - 1400nm
IR-B	1400nm - 3000nm
IR-C	3000nm - 1 mm



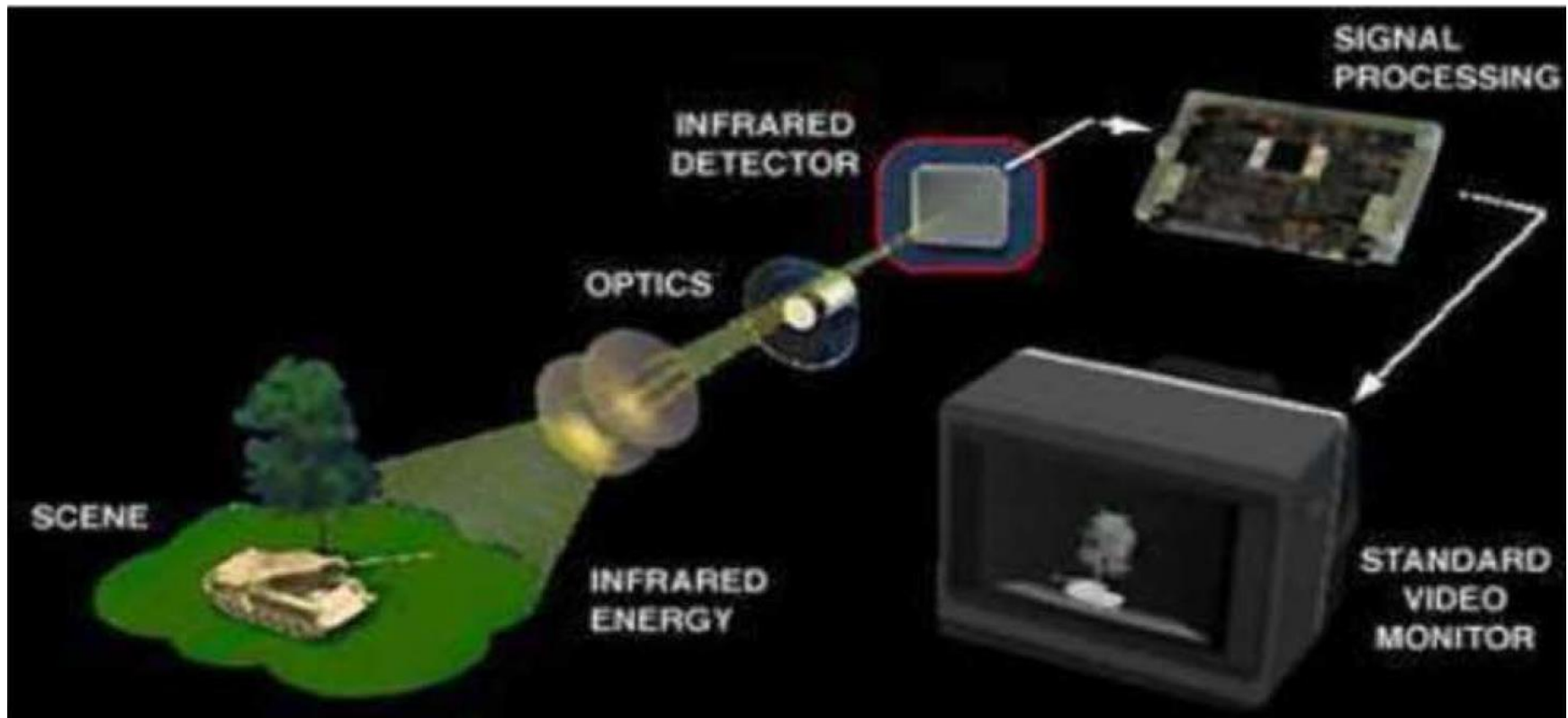


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WORKING OF THERMAL IMAGING CAMERA



A thermal imaging camera consists of five components: an optic system, detector, amplifier, signal processing, and display





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How infrared cameras work



- All objects emit infrared energy, known as a heat signature. An infrared camera (also known as a thermal imager) detects and measures the infrared energy of objects. The camera converts that infrared data into an electronic image that shows the apparent surface temperature of the object being measured.
- An infrared camera contains an optical system that focuses infrared energy onto a special detector chip (sensor array) that contains thousands of detector pixels arranged in a grid.
- Each pixel in the sensor array reacts to the infrared energy focused on it and produces an electronic signal. The camera processor takes the signal from each pixel and applies a mathematical calculation to it to create a color map of the apparent temperature of the object. Each temperature value is assigned a different color. The resulting matrix of colors is sent to memory and to the camera's display as a temperature picture (thermal image) of that object.
- Many infrared cameras also include a visible light camera that automatically captures a standard digital image with each pull of the trigger. By blending these images it is easier to correlate problem areas in your infrared image with the actual equipment or area you are inspecting.
- Fusion technology combines a visible light image with an infrared thermal image with pixel-for-pixel alignment. You can vary the intensity of the visible light image and the infrared image to more clearly see the problem in the infrared image or locate it within the visible light image.
- Beyond basic thermal imaging capabilities, you can find infrared cameras with a wide range of additional features that automate functions, allow voice annotations, enhance resolution, record and stream video of the images, and support analysis and reporting.

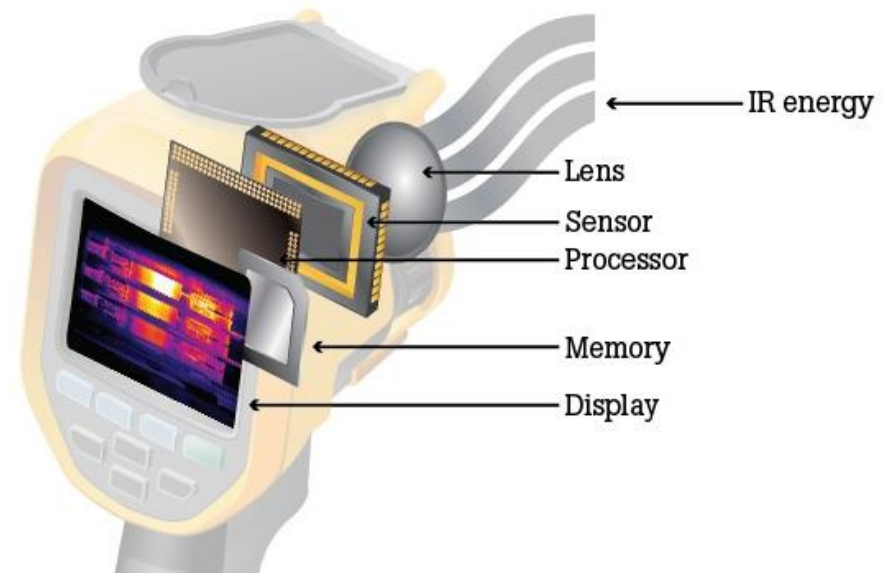
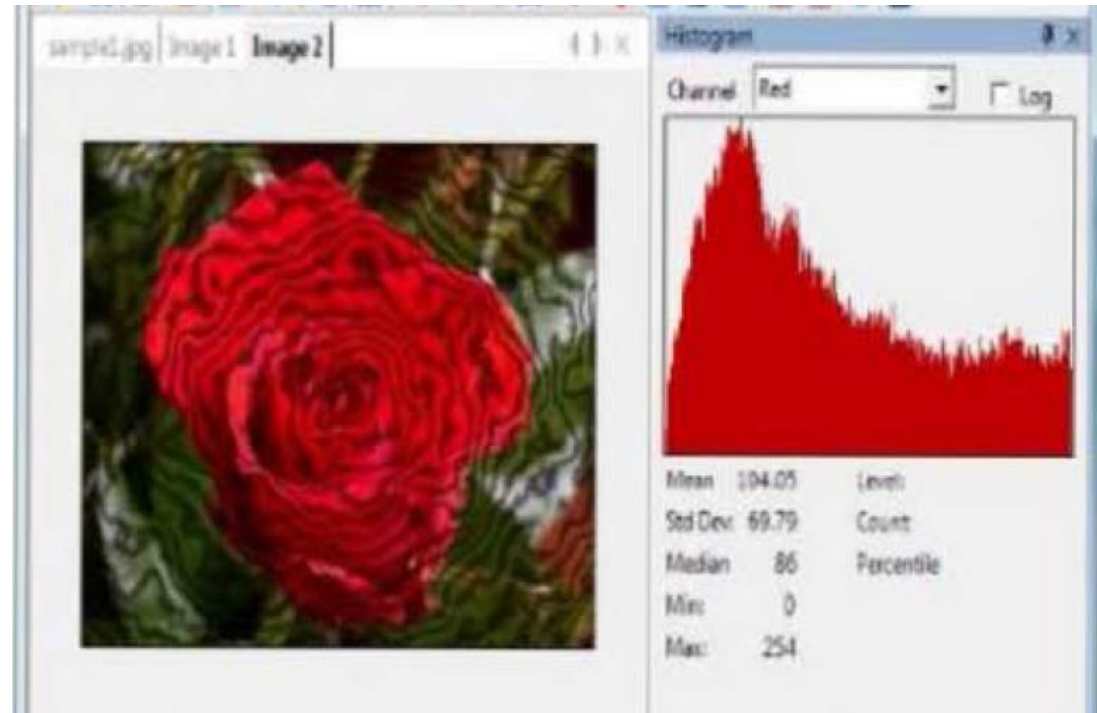


IMAGE PROCESSING

Image processing is any form of signal processing for which the input is an image, such as a photograph or video frame and the output may be either an image or a set of characteristics or parameters related to the image



COMPONENTS OF THERMAL IMAGING CAMERA

- An optic system
 - Lens
- Detector
 - Cooled Detector
 - Uncooled Detector
- Amplifier
- Signal processing
- Display
 - Standard Video Monitor



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TYPES OF THERMAL IMAGING CAMERAS



- **COOLED THERMAL IMAGER**
- Cooled detectors are typically contained in a vacuum-sealed case and cryogenically cooled
- Cooling is necessary for the operation of the semiconductor materials used else they would be blinded by their own radiation
- Cooled inf rared cameras provide superior image quality
- Bulky and expensive to produce and run
- Cooling is power-hungry and time-consuming hence the camera needs time to cool down before it can be used
- **UNCOOLED THERMAL IMAGER**
- Un-cooled detectors use a sensor operating at ambient temperature, or a sensor stabilized at room temperature using control elements
- Resolution and image quality tend to be lower than cooled detectors
- Smaller and less costly to produce and run
- Fast operation and consumes less power



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Uncooled vs Cooled Thermal Comparison (640 X 480)



Uncooled



Cooled



THERMAL IMAGING APPLICATIONS

- INDUSTRIAL APPLICATIONS
- MEDICINE APPLICATIONS
- SECURITY APPLICATIONS
- BUILDING CONSTRUCTIONS
- NIGHT VISION



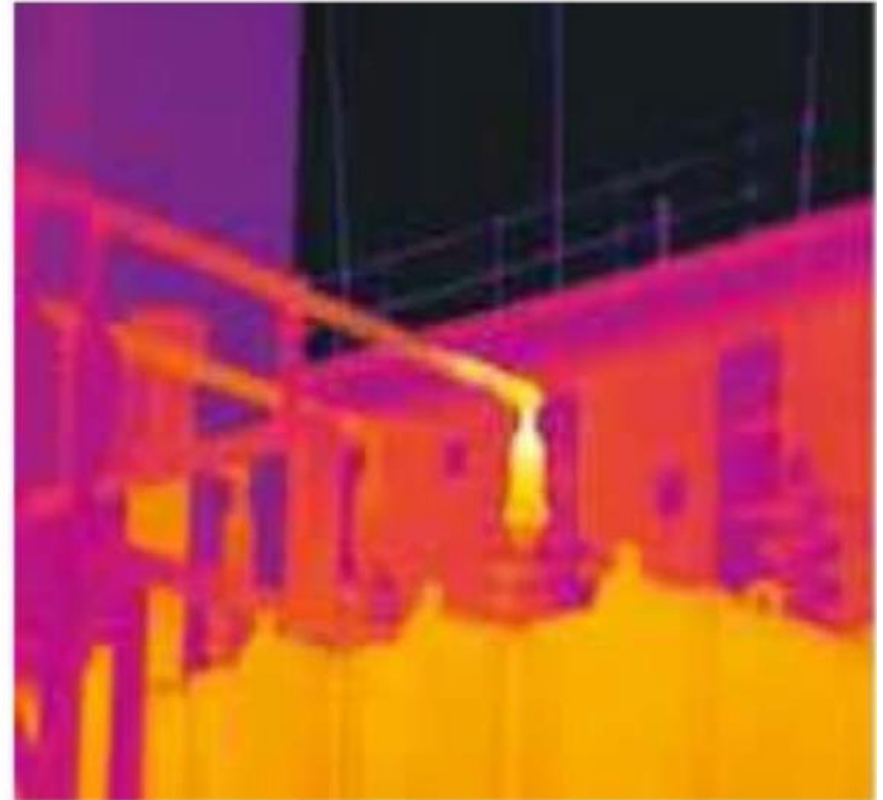
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THERMAL IMAGING IN INDUSTRIAL APPLICATIONS



- Whether you're monitoring high voltage equipment, low voltage cabinets, motors, pumps, high temperature equipment, looking for insulation losses ... A thermal imaging camera is the one tool that really lets you SEE it all.
- Electrical Systems
 - Low Voltage Installations
 - High Voltage Installations
- Mechanical Installations

HIGH VOLTAGE INSTALLATIONS

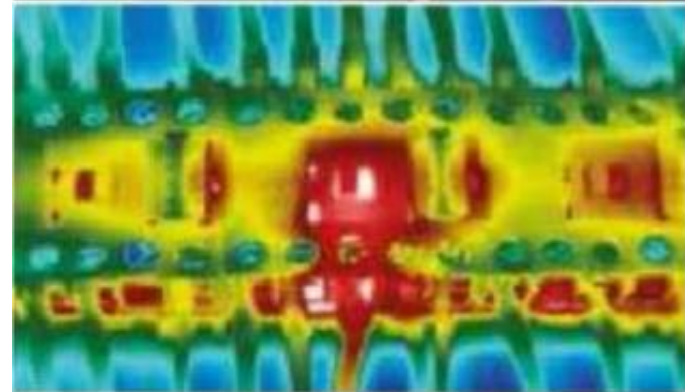
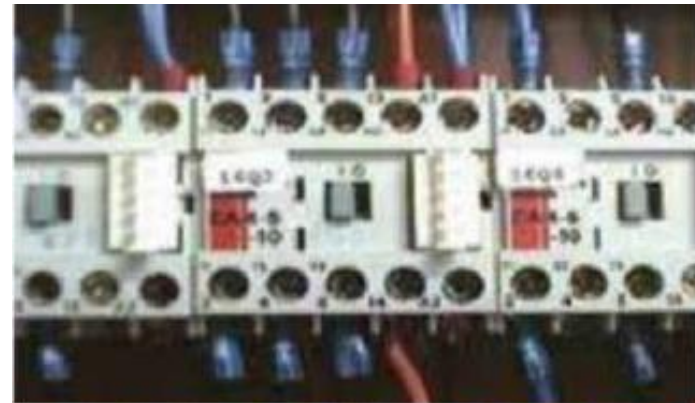
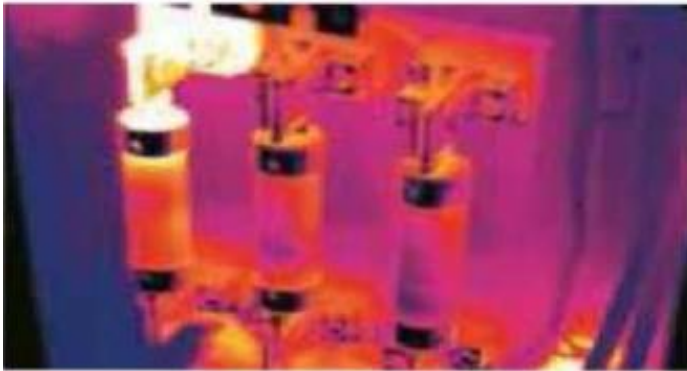




LOW VOLTAGE INSTALLATIONS

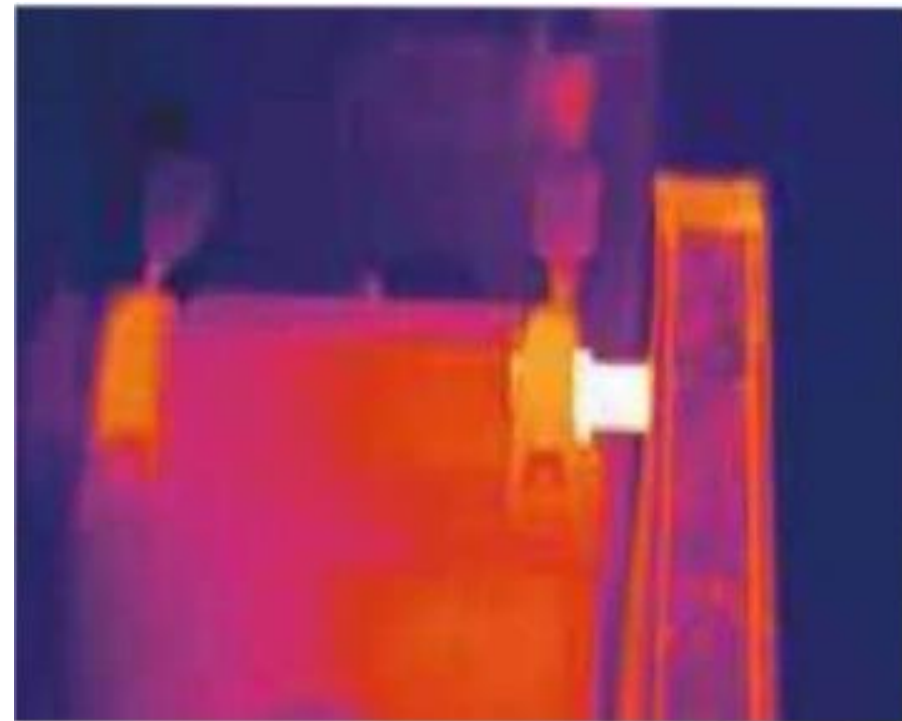


- Over heated connections
- Hot spots shows Short circuit



MECHANICAL INSTALLATIONS

- Suspected Roller
- Over heated bearing





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THERMAL IMAGING IN MEDICINE



- The technique essentially uses naturally emitted infrared radiation from the skin surface.
- The credibility and acceptance of thermal imaging in medicine is subject to critical use of the technology and proper understanding of thermal physiology.
- Finally, we review established and evolving medical applications for thermal imaging, including inflammatory diseases
- Currently, there is interest in the use of thermal imaging for fever screening

FEVER SCREENING

- Shows the detection of SARS and Swine flu among passengers using Thermal Imaging Technology





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THERMAL IMAGING IN BORDER SECURITY



- Due to their ability to detect man sized targets at extremely long distances in total darkness and in extreme weather conditions thermal imaging cameras are extremely suited for border surveillance.
- Generally, cooled cameras are used in border security applications as they provide a longer range performance than un-cooled detector.
- If the terrain is e.g. mountainous and does not permit seeing over a distance of 20 kilometers, un-cooled thermal imaging cameras can be used for border security as well.
- Thermal imaging cameras can be integrated with radar systems.

THERMAL IMAGING IN BORDER SECURITY





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THERMAL IMAGING IN SECURITY AND LAW ENFORCEMENT



- With a thermal imager, an officer can stop and scan the property at a distance, identifying any person present there.
- Perimeter surveillance is another application in which thermal imaging can be used to dramatically improve results and reduce the time committed to a particular operation.
- Thermal imaging cameras are also used in search and rescue operations as officers may be able to search up to 1, 500 feet in any direction.



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THERMAL IMAGING IN SECURITY AND LAW ENFORCEMENT



- Thermal Image of a person hiding behind truck
- Thermal Image of Search and Rescue operation





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THERMAL IMAGING IN NIGHT VISION

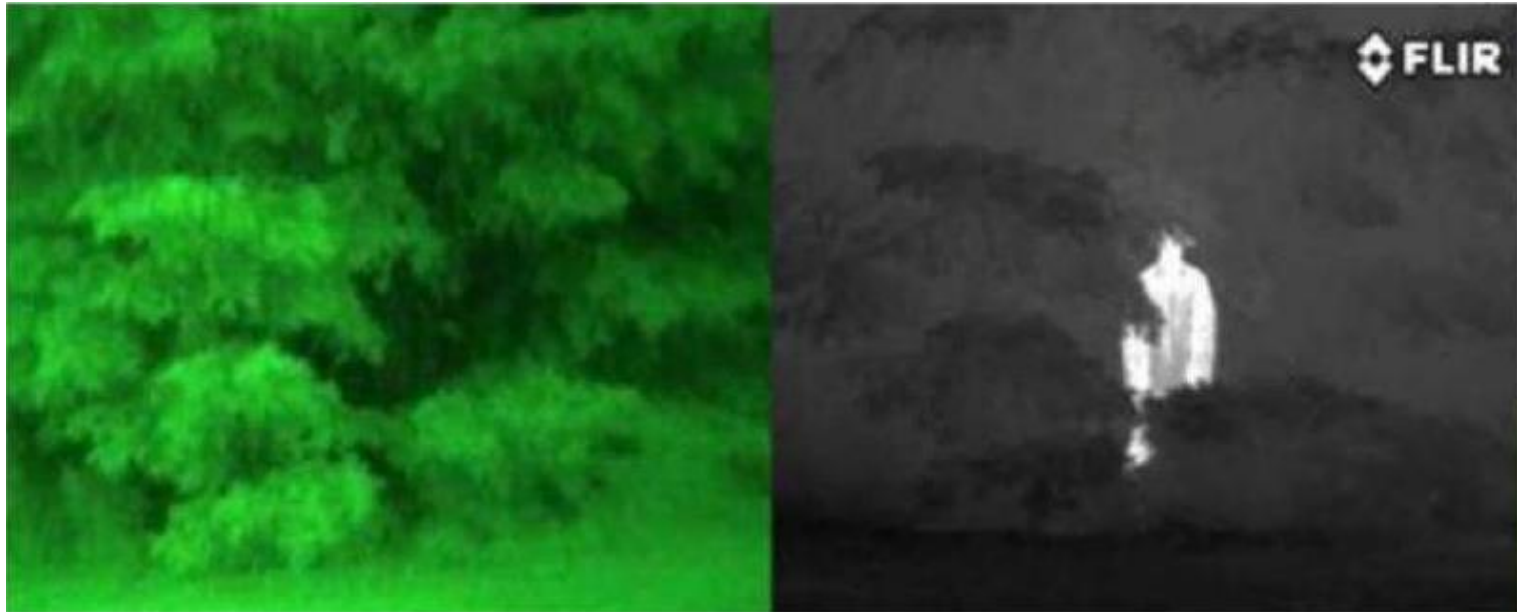


- Thermal imaging cameras are excellent tools for night vision.
- They detect thermal radiation and do not need a source of illumination .
- They produce an image in the darkest of nights and can see through light fog, rain and smoke.
- Thermal imaging cameras are widely used to complement new or existing security networks, and for night vision on aircraft, where they are commonly referred to as "FLIR" (for "forward-looking infrared".)



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THERMAL IMAGING IN NIGHT VISION





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THERMAL IMAGING IN BUILDING DIAGNOSTICS



- Thermal cameras show exactly where the problems are quickly and help detecting energy waste, moisture and electrical issues in buildings .
- Thermal imaging is used for maintenance of electrical, mechanical, and structural systems, to detect problems, prevent downtime, guide corrective action, and increase work safety .
- Using thermal imagers it's easy to scan an entire building to detect building envelope, and plumbing issues, presence of moisture in building envelopes, either from leakage or condensation and water damage.



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THERMAL IMAGING IN BUILDING DIAGNOSTICS



Tub leak in the ceiling found Thermal Image of a house



OTHER APPLICATIONS

- Evaluation of Solar Panels
- Thermal mapping
- Archaeological kite aerial thermography
- Veterinary Thermal Imaging
- Food and Agriculture
- Research
- Weather Forecasting
- Nondestructive testing
- Defense
- Chemical imaging
- Volcanology

Advantages



- Non-invasive and non-destructive hence can be used to survey whilst the plant and equipment is running, in production and on load
- Produces fast, accurate and immediate temperature measurement and helps in fault detection
- Cameras are easy to install and surveys can be performed at a convenient time.
- Is capable of catching moving targets in real time and in low light conditions
- Can be used to measure or observe subjects in areas inaccessible or hazardous for other methods
- Can help in identifying air leakages, documenting irregular heat dispersion and identifying possible irregularities in insulation
- Cameras can passively see all objects, regardless of ambient light.

Limitations

- Quality cameras are expensive (often US\$ 3, 000 or more), cheaper are only 40x40 up to 120x120 pixels .
- Images can be difficult to interpret accurately when based upon certain objects, specifically objects with erratic temperatures .
- Accurate temperature measurements are hindered by differing emissivities and reflections from other surfaces .
- Most cameras have +2% accuracy or worse in measurement of temperature and are not as accurate as contact methods .
- Only able to directly detect surface temperatures .
- Thermal imaging cameras cannot be used to see objects under water
- Because thermal energy can be reflected off shiny surfaces, thermal imaging cameras cannot see through glass.
- Also thermal imaging cameras cannot see through walls.

Conclusions

- Thermography deals with helping individuals see what the naked eye cannot.
- However, helping you see even when there is no light is only a fraction of what thermal imaging is used for.
- With the use of special cameras and lenses, this technology offers benefits ranging from industrial advantages, down to law enforcement.

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