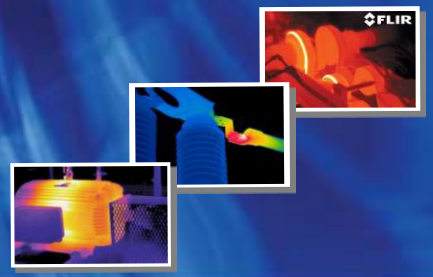
FLIR SYSTEMS
The Global Leader in Infrared Cameras



Infrared Imaging

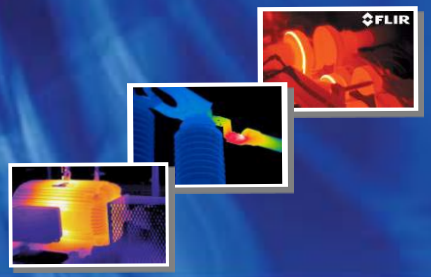
Digital Imaging Systems, lecture 15

January 2009

Malin Ingerhed

FLIR SYSTEMS
The Global Leader in Infrared Cameras

Outline



IR basics

Applications

Detector technologies

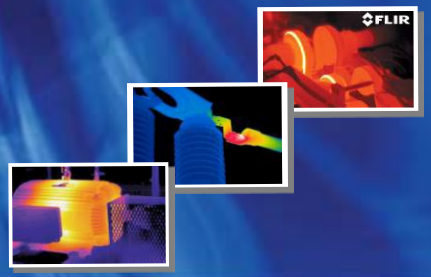
Data processing

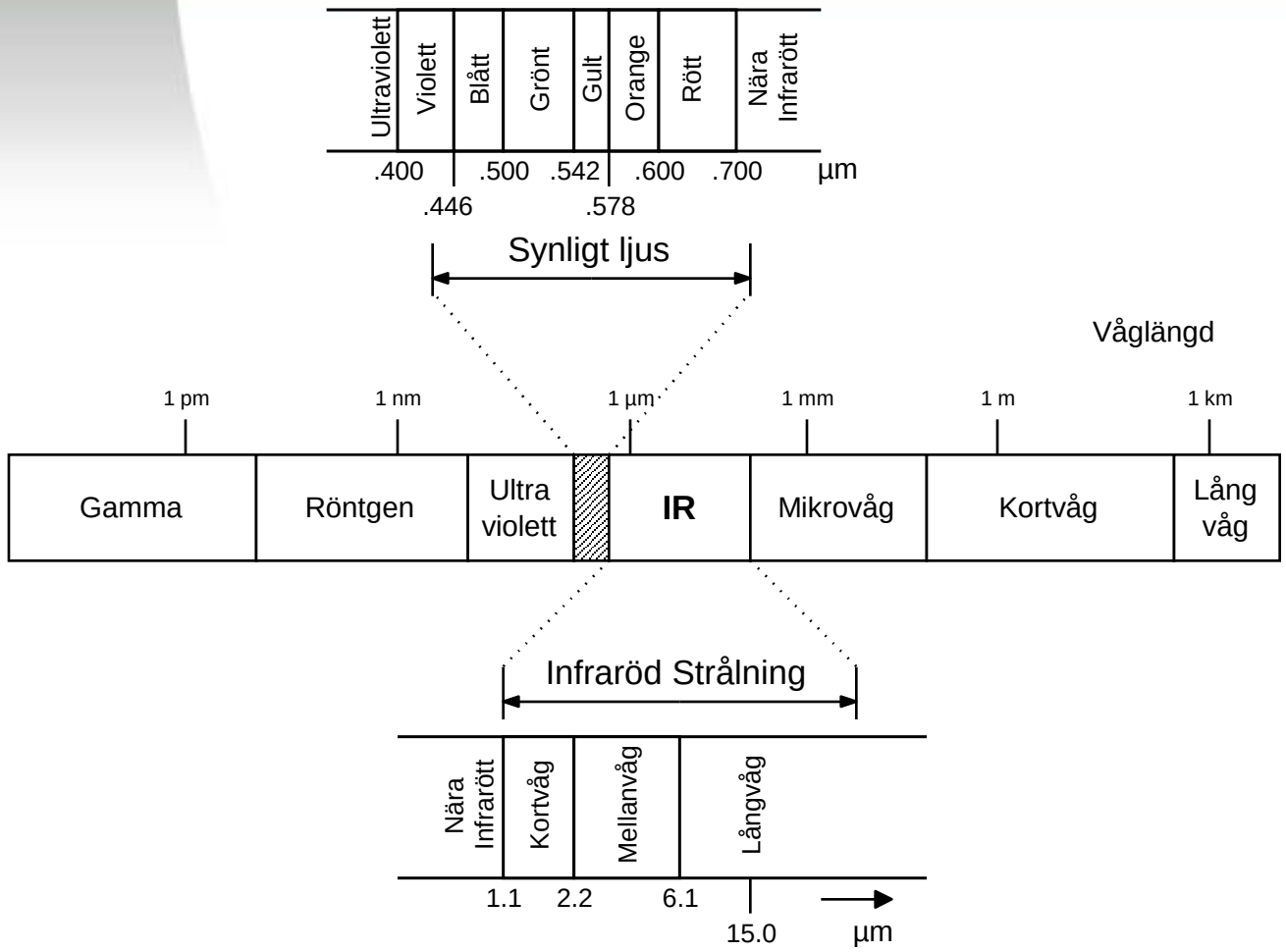
Image quality

Quick course in data sheet reading

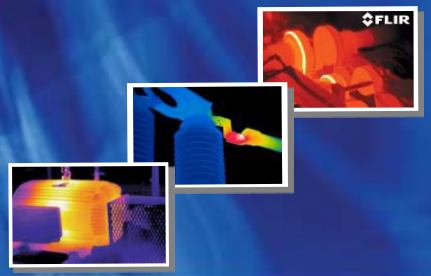
Future development

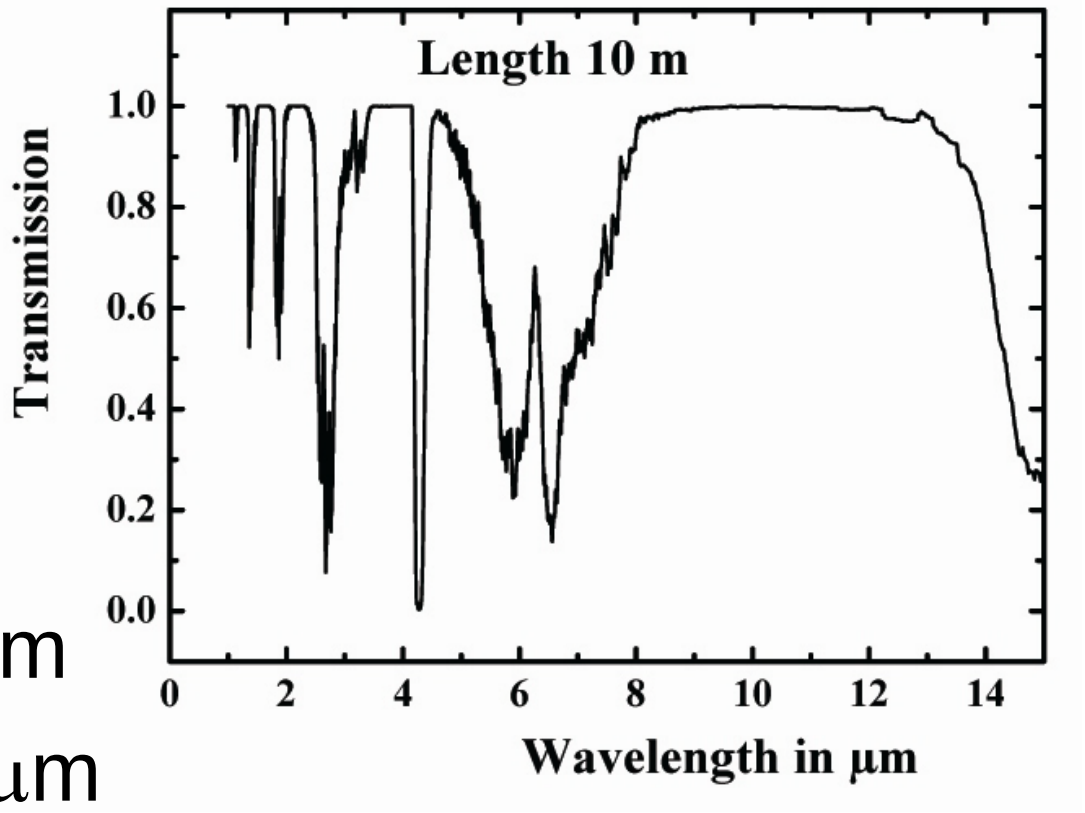
Infrared spectrum





Transmission in air

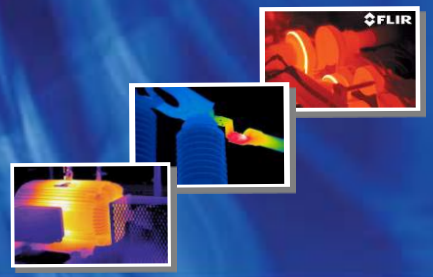




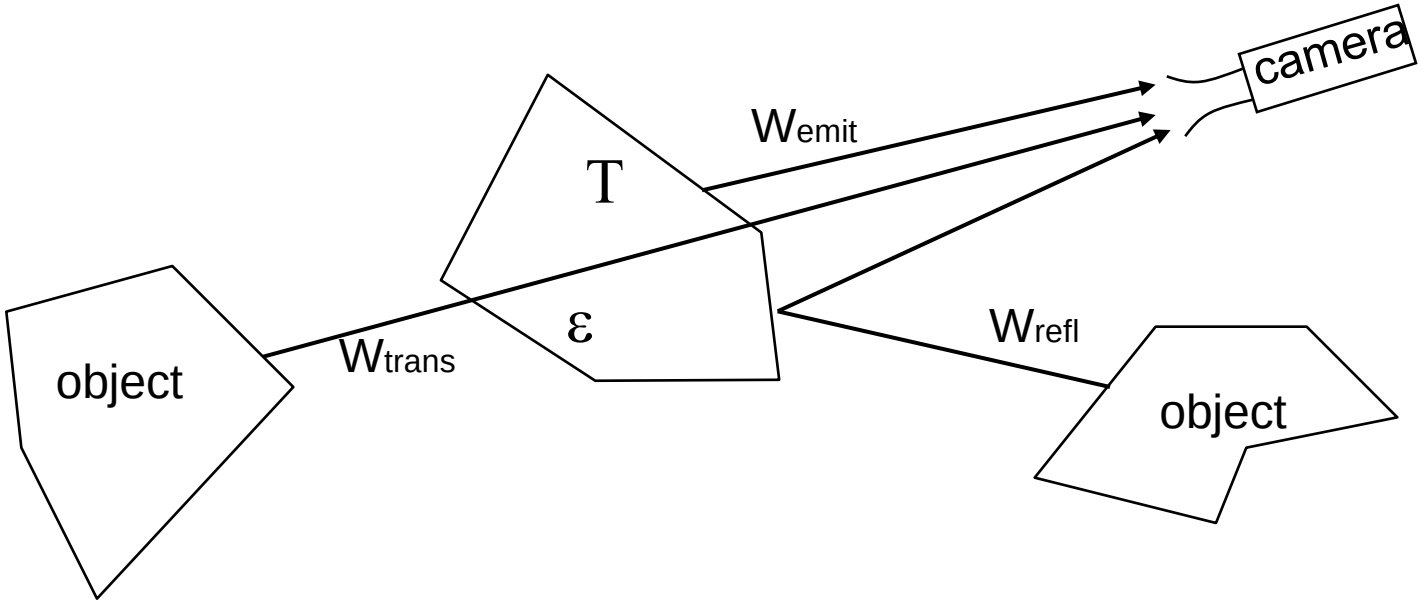
Shortwave: 2-5µm

Longwave: 8-14µm

Reflection, transmission, emission



Radiation captured by the camera consists of reflected, transmitted and emitted radiation.



Problems with reflections

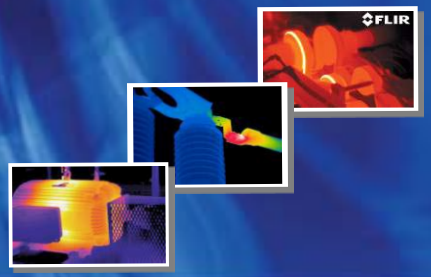
Transmission is usually not a problem, very few materials are transparent enough in IR

Reflection is a large problem

- Large effect on measurements
- Difficult to avoid

FLIR SYSTEMS
The Global Leader in Infrared Cameras

Emissivity

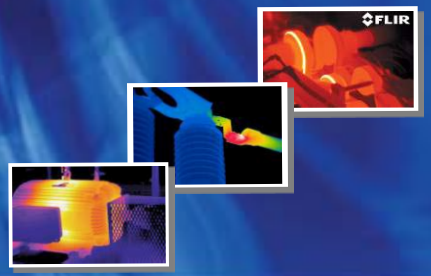


The emission from an object depends on the object temperature, T, and the emissivity, ε, of the object.

Emissivity depends on the material. Surface usually have large importance.

Emissivity is a user adjusted parameter in the camera that must be correct to get correct mesurements

Radiometric cameras (thermography cameras)



Temperature measuring cameras.

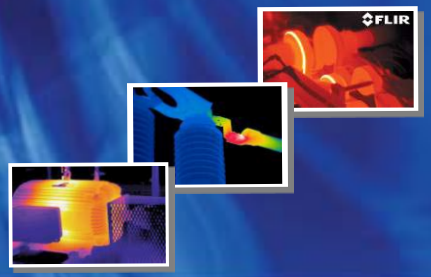
Needs: Calibration
Temperature compensation

Temperature cykling during production gives parameters for temperature compensation.

Individual calibration of each camera

FLIR SYSTEMS
The Global Leader in Infrared Cameras

Applications, military



Different kinds of surveillance

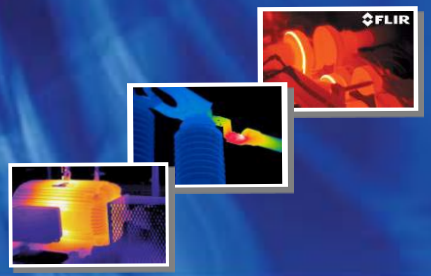
- Airborne
- Maritime
- Landborne

Semi-military application

- Border control

FLIR SYSTEMS
The Global Leader in Infrared Cameras

Thermography cameras



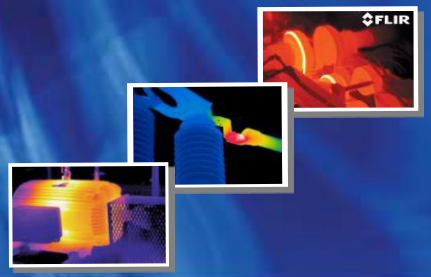
NEC

FLIR

FLUKE

FLIR SYSTEMS
The Global Leader in Infrared Cameras

Thermography cameras



Three market segments

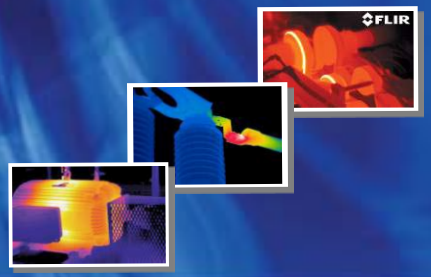
High volume: Low resolution, low framerate, low price

High end: Good image quality, lots of features, high price

R&D: High framerate, long recording, very good image quality, expensive

FLIR SYSTEMS
The Global Leader in Infrared Cameras

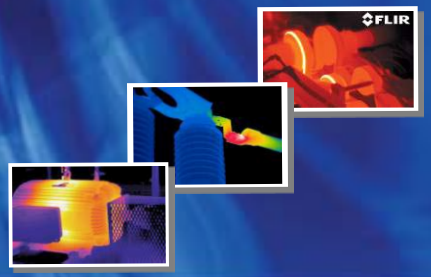
Aplications, commercial



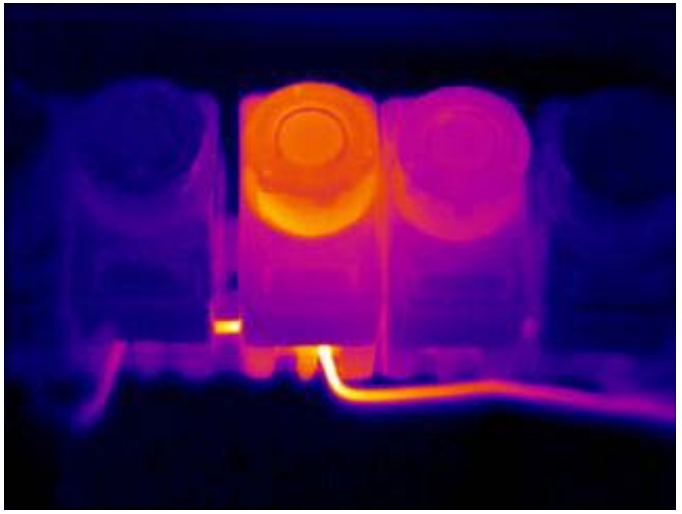
- Electrical
- Building
- Energy saving
- Gas detection
- Night vision, cars and boats
- Automation
- Security
- R&D

FLIR SYSTEMS
The Global Leader in Infrared Cameras

Electrical

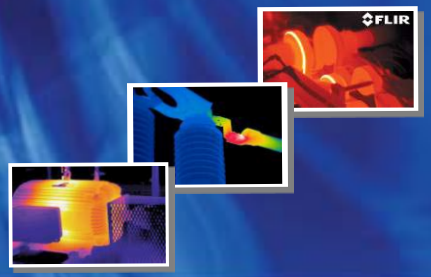


The oldest commercial application

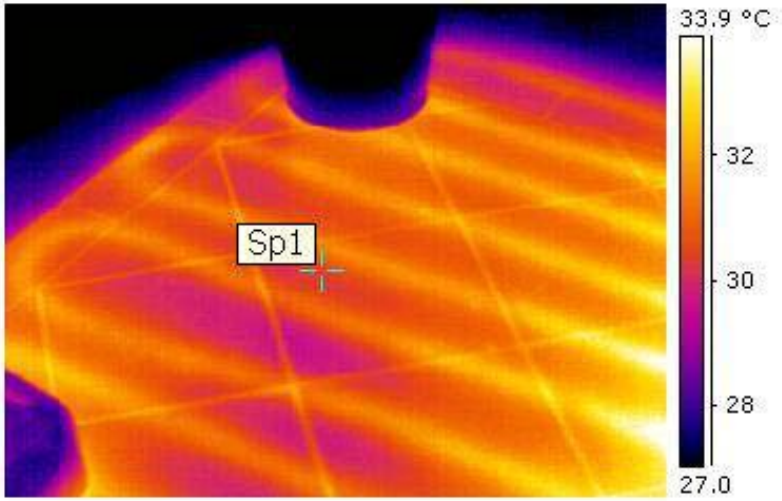


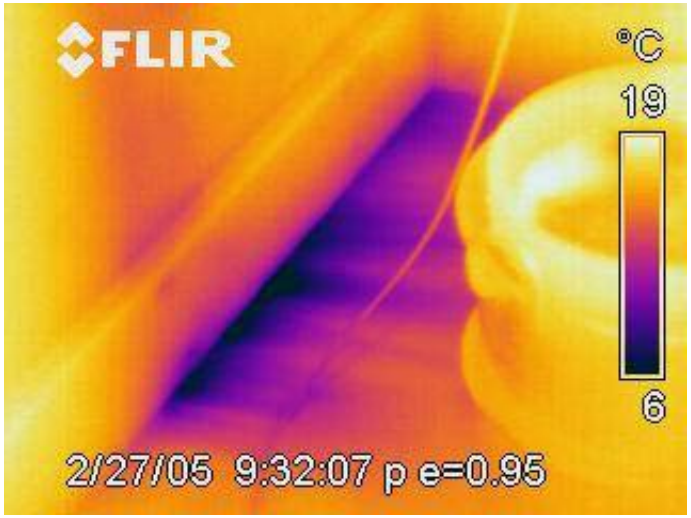
FLIR SYSTEMS
The Global Leader in Infrared Cameras

Building



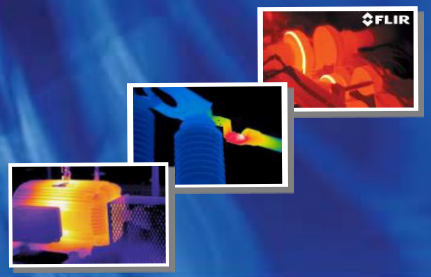
Fastly growing application



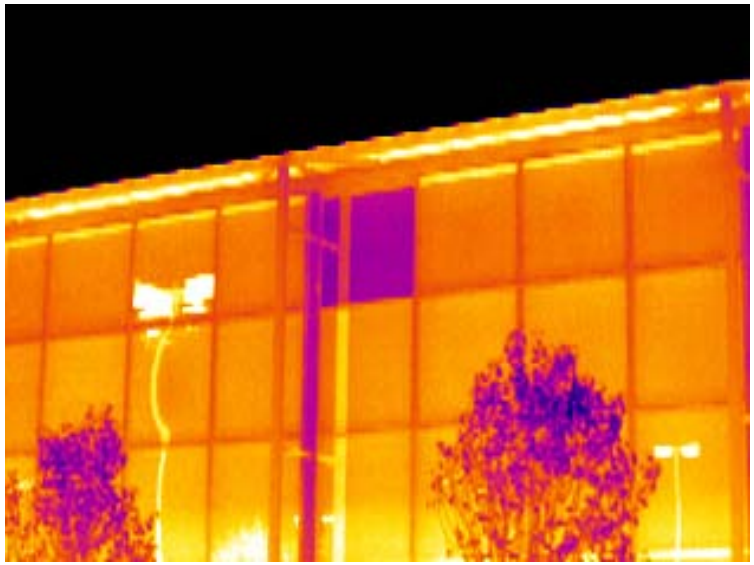


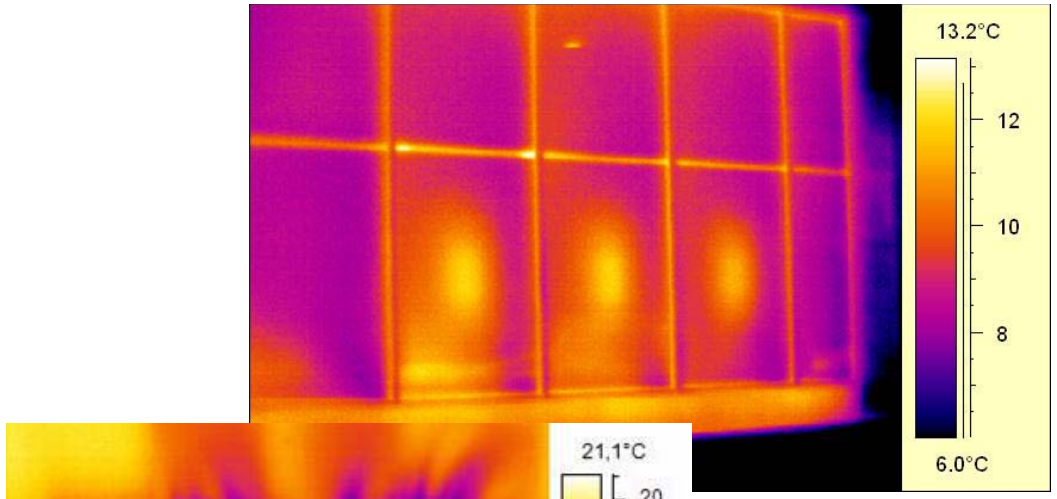
FLIR SYSTEMS
The Global Leader in Infrared Cameras

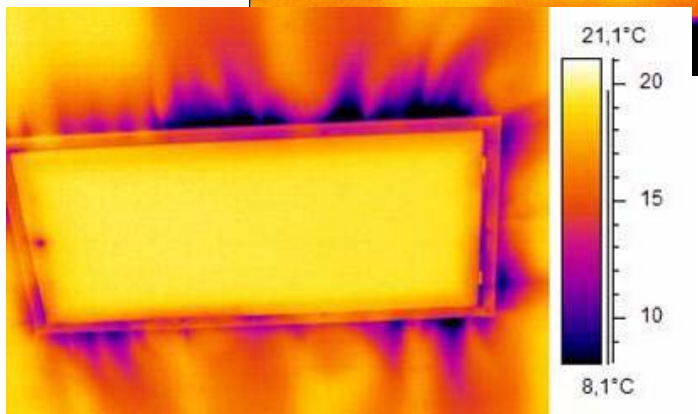
Energy



According to EU regulations all buildings must have an energy declaration

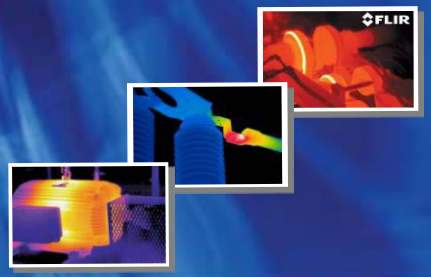


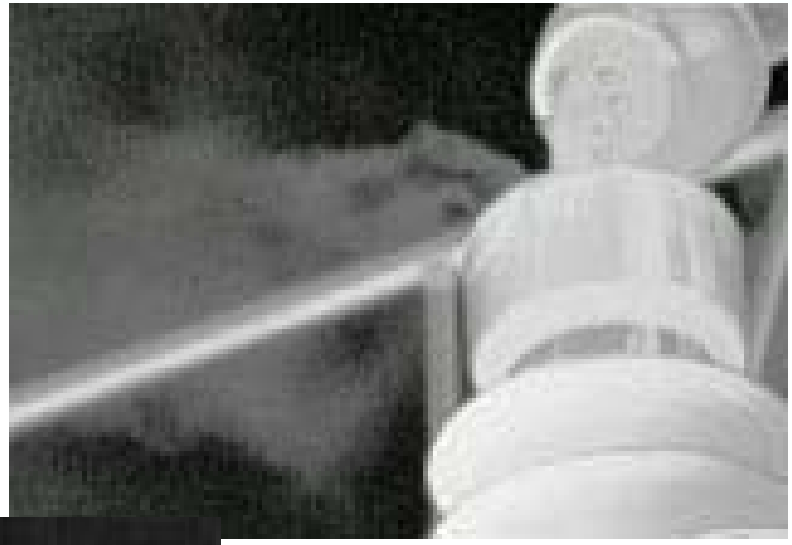


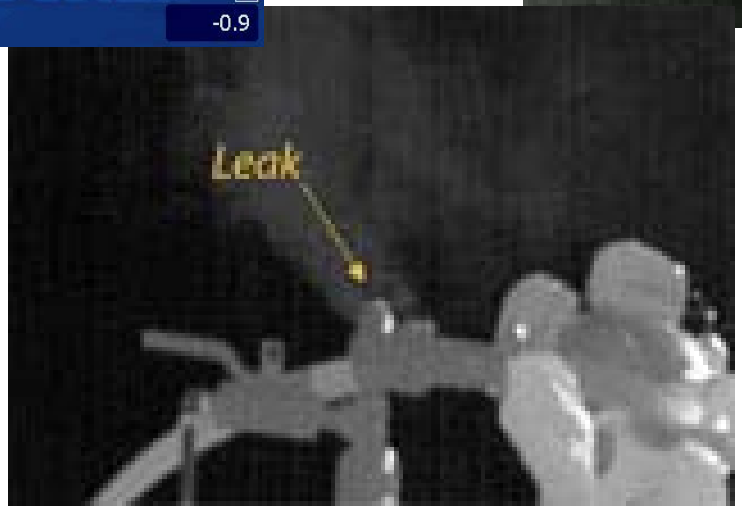


FLIR SYSTEMS
The Global Leader in Infrared Cameras

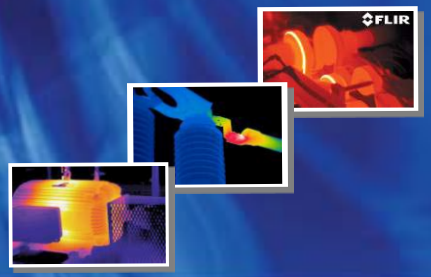
Gas detection







Gas detection (cont.)



A number of commercially important gases can be detected. Different gases is visible in different wave lenghts due to absorption characteristics of the gas.

Special cameras with very narrow wave-lenght used

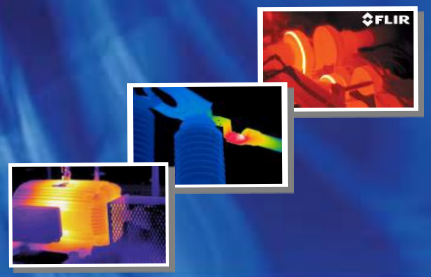
Example of gases visible in mid-wave

Benzene	Pentane
Ethanol	1-Pentene
Ethylbenzene	Toluene
Heptane	Xylene
Hexane	Butane
Isoprene	Ethane
Methanol	Methane
MEK	Propane
MIBK	Ethylene
Octane	Propylene

Visible in long wave: Most important SF_6

FLIR SYSTEMS
The Global Leader in Infrared Cameras

Night vision

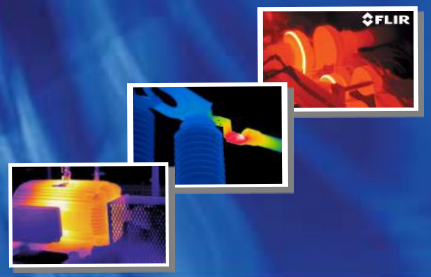


Cars: pedestrian aviodance

Boats: navigation
search-and-rescue

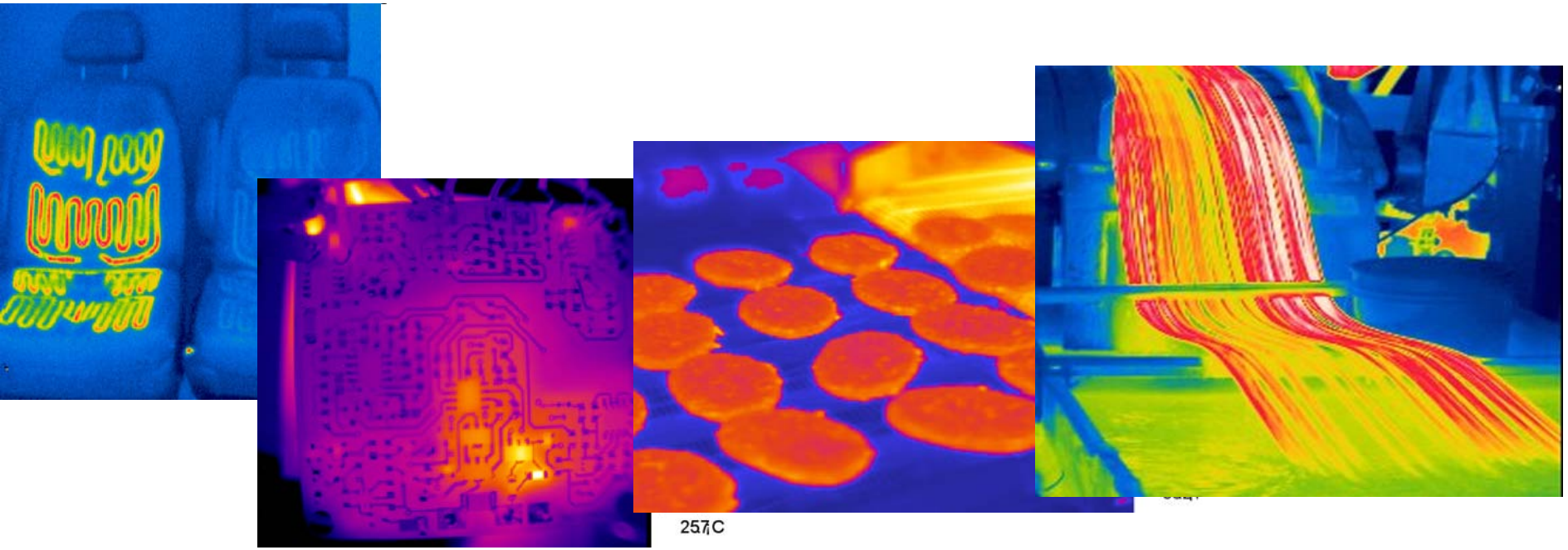
FLIR SYSTEMS
The Global Leader in Infrared Cameras

Automation

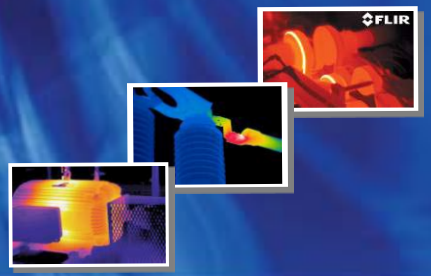


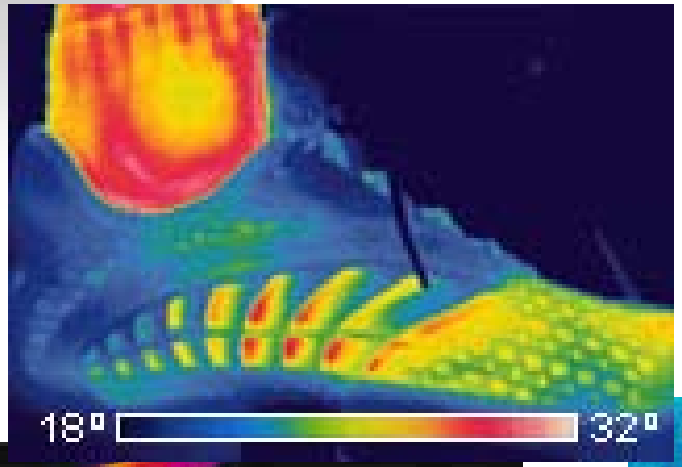
A wide range of different areas

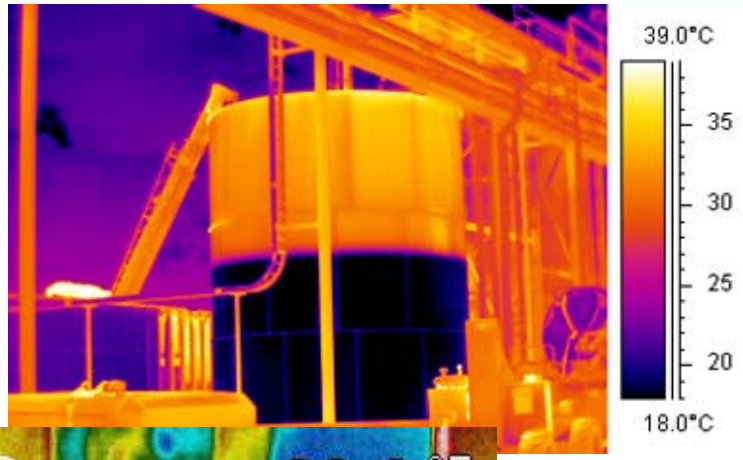
IR-cameras often part of a large system for quality assurance and fault detection

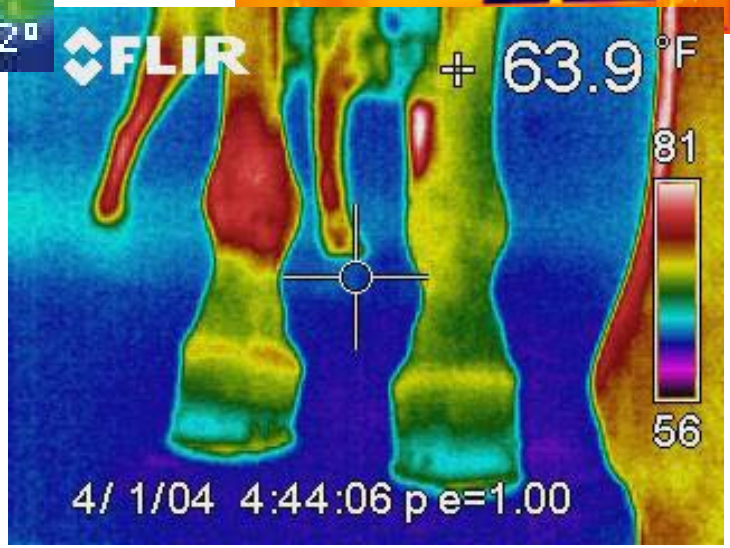


FLIR SYSTEMS
The Global Leader in Infrared Cameras

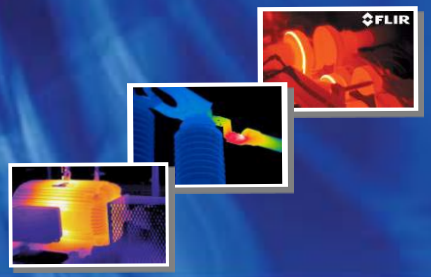








Detectors



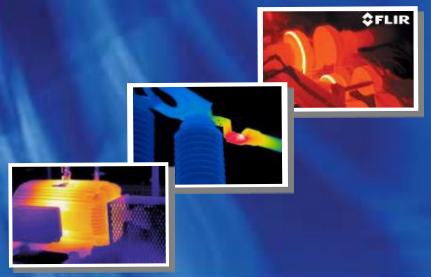
Early IR cameras were scanning systems

One single detector element received radiation from all points in the scen by projecting the points on to the detector

Cameras with 2D detectors (FPA) intrduced around 1990

FLIR SYSTEMS
The Global Leader in Infrared Cameras

Detector technologies



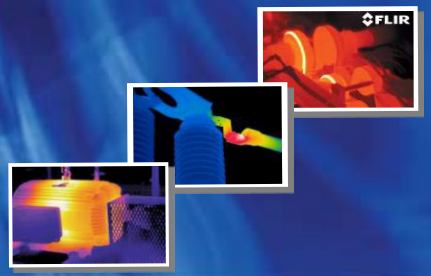
Uncooled detectors

Micro bolometer, amorphous silicon
VOX

Cooled detectors

InSb
QWIP
MCT

Micro bolometers

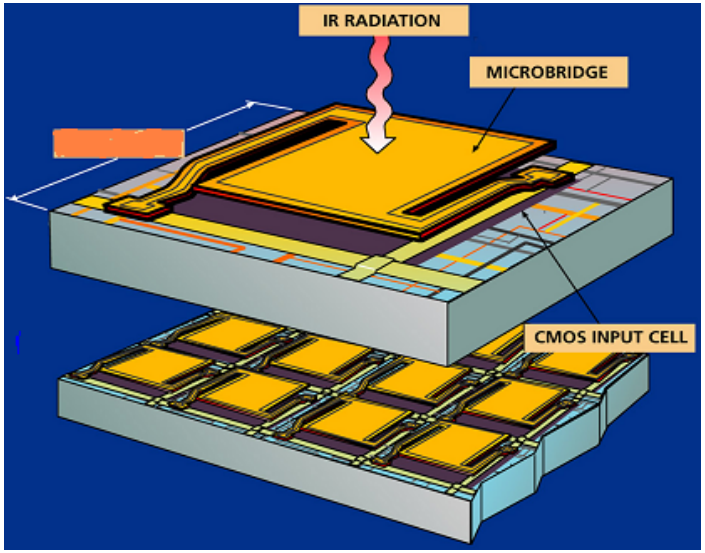


Bolometers resistance decrease when bolometer temperature increase

Two different materaials: amorphous silicon, VOX

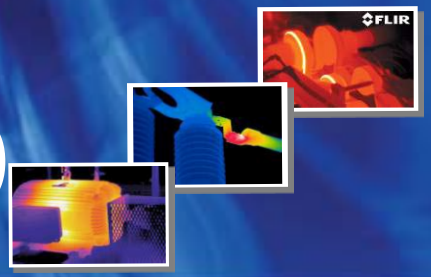
Uncooled

Wavelenght 8-14μm



FLIR SYSTEMS
The Global Leader in Infrared Cameras

InSb (Indium Antimonide)



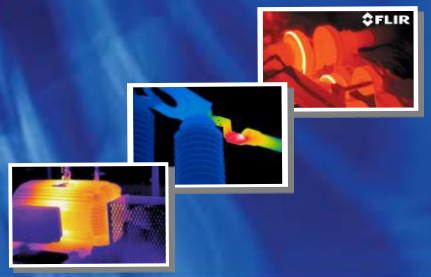
InSb generates current when exposed to infrared radiation

Operating temperature: 80 K

Wavelenght: visible-5,5 μm

FLIR SYSTEMS
The Global Leader in Infrared Cameras

QWIP detectors



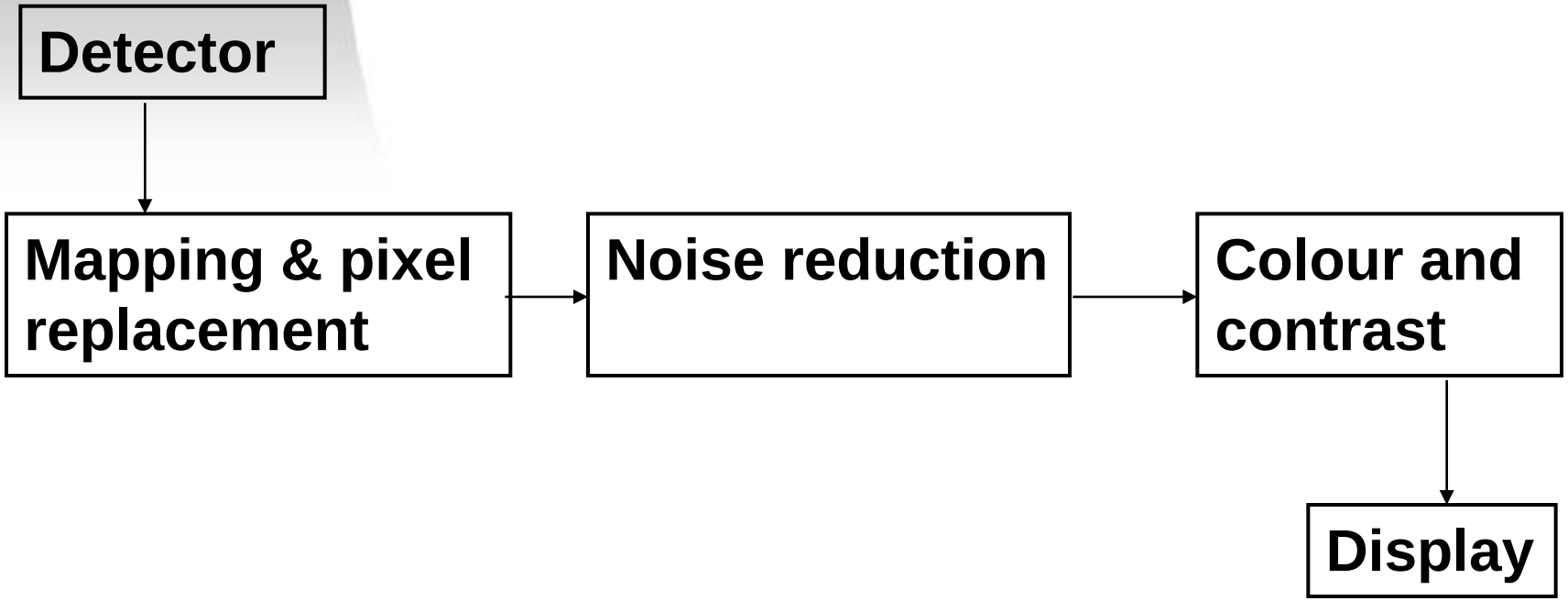
QWIP = Quantum Well Infrared Photodetectors

Output signal proportional to number of infalling photons

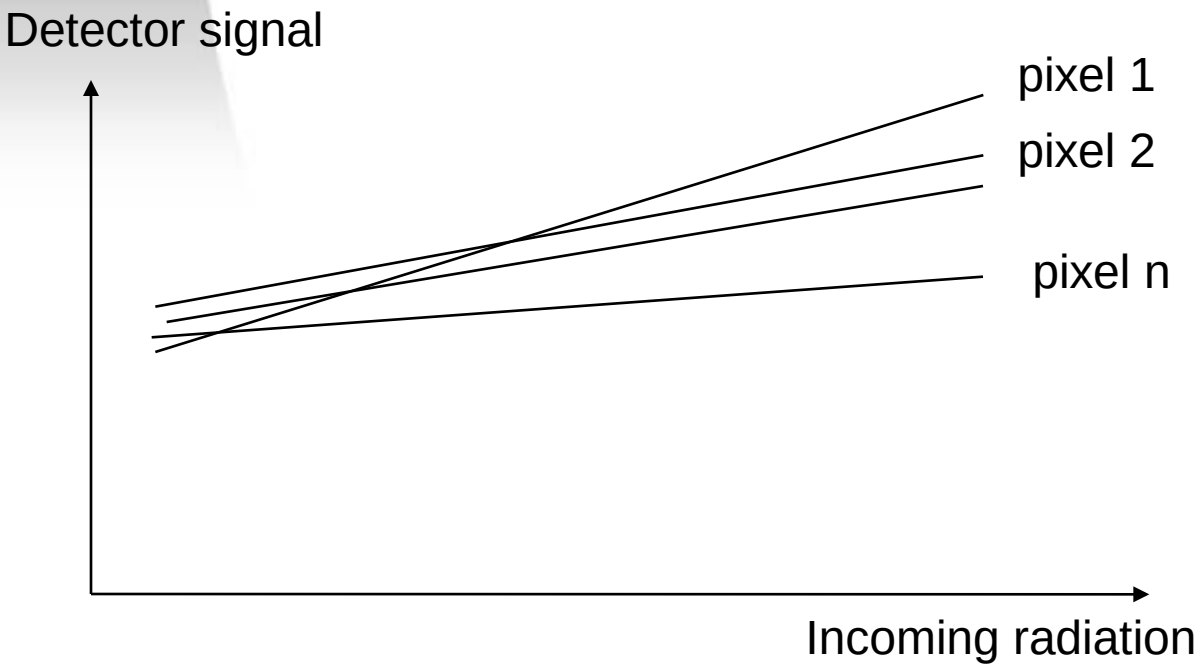
Different materials and material structures gives different wavelenghts.

Different operating temperatures for different wavelenghts. 50-70K

Data processing from detector to display



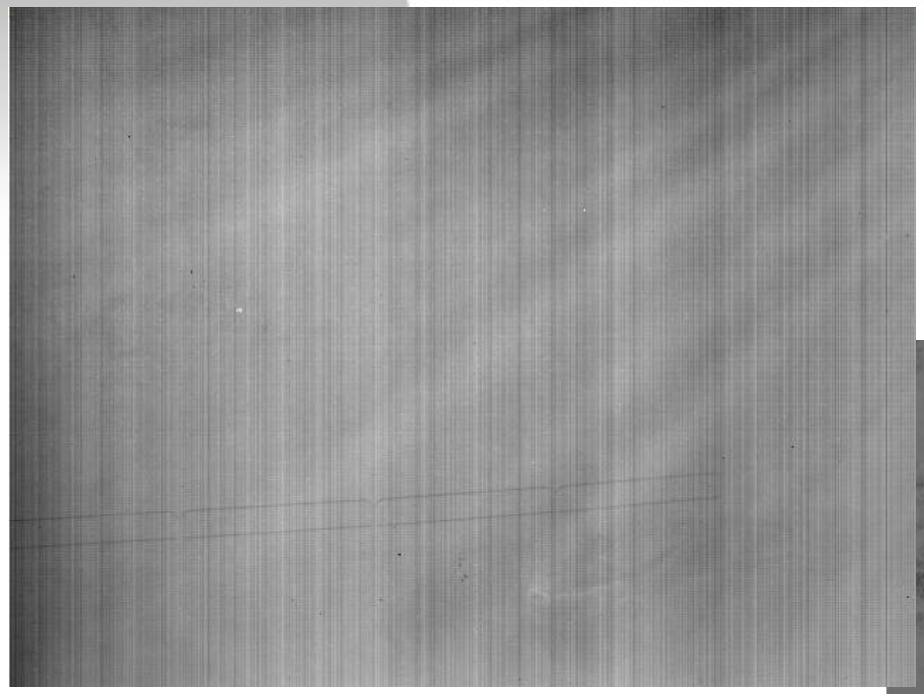
Mapping and pixel replacement



Necesssary with pixelvise gain and offset compensation $I(x,y) = a(x,y)*I_o(x,y)+b(x,y)$

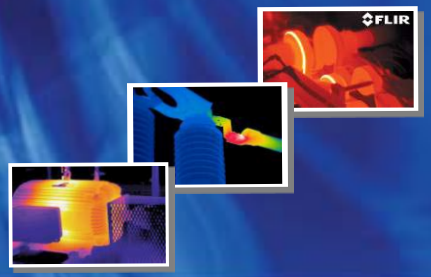
FLIR SYSTEMS
The Global Leader in Infrared Cameras

Mapping



FLIR SYSTEMS
The Global Leader in Infrared Cameras

Mapping (cont.)



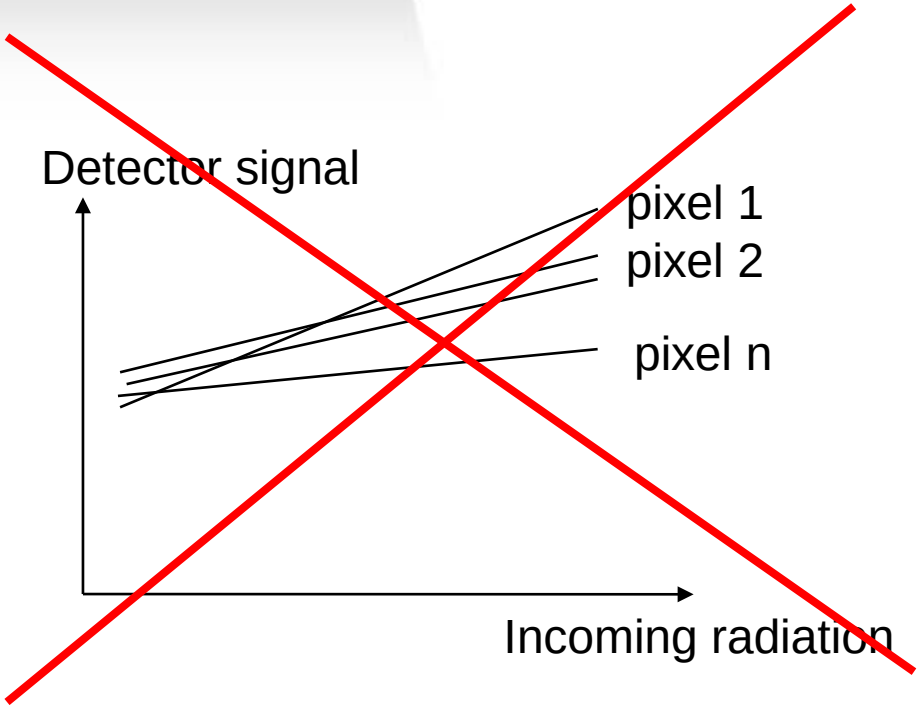
Usually: Maps computed and stored in the camera during production.

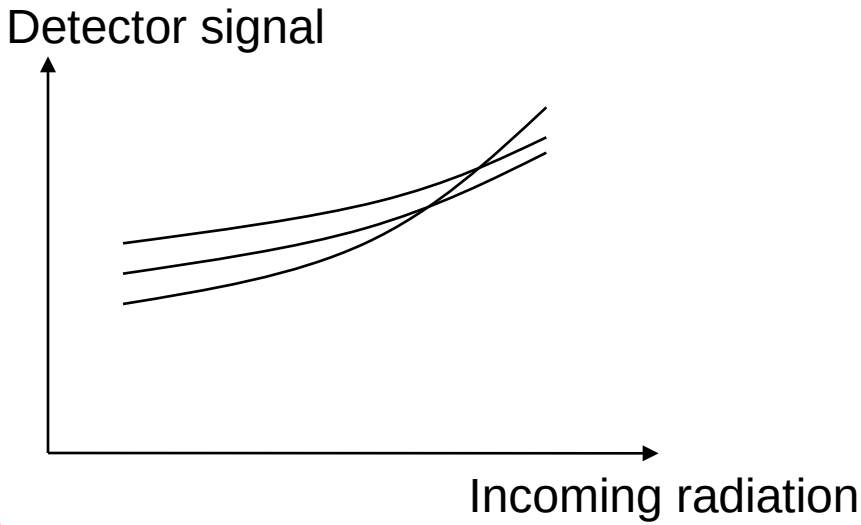
Additional offset correction map computed during use of the camera.

The offset map is computed using a shutter flag.

Mapping (cont.)

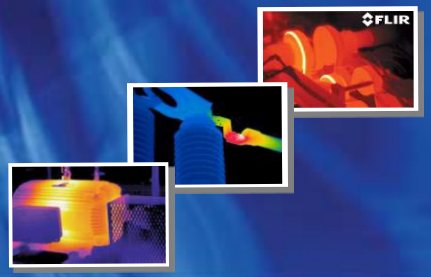
Detector elements non-linear





FLIR SYSTEMS
The Global Leader in Infrared Cameras

Pixel replacement



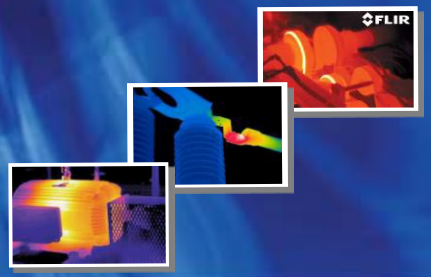
Pixels from low quality detector elements must be replaced.

The main problem is detction of these pixels. Pixels can be bad in many different ways.

Examples of types of bad pixels: spatial, temporal, gain deviation

FLIR SYSTEMS
The Global Leader in Infrared Cameras

Detection of bad pixels

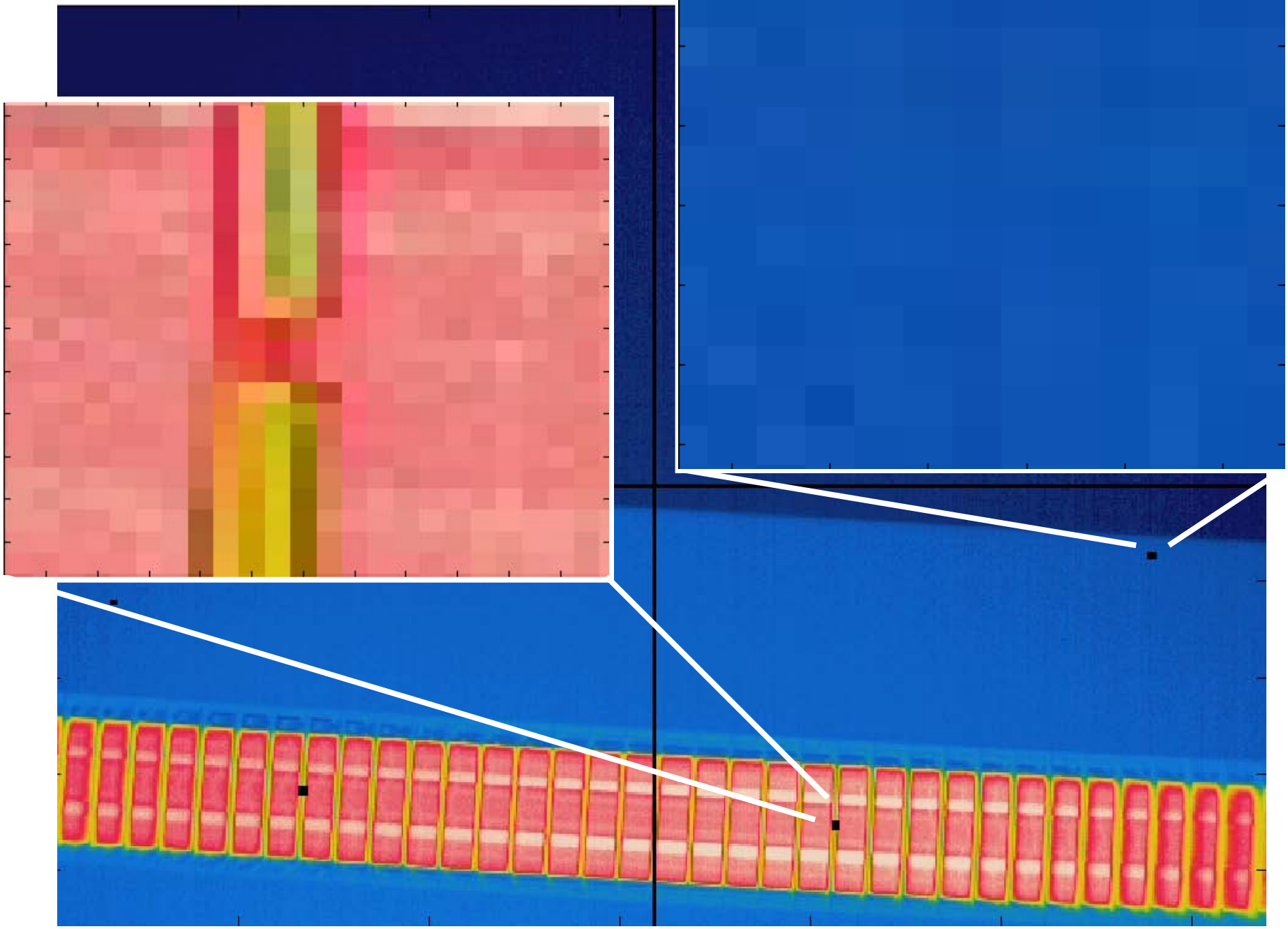


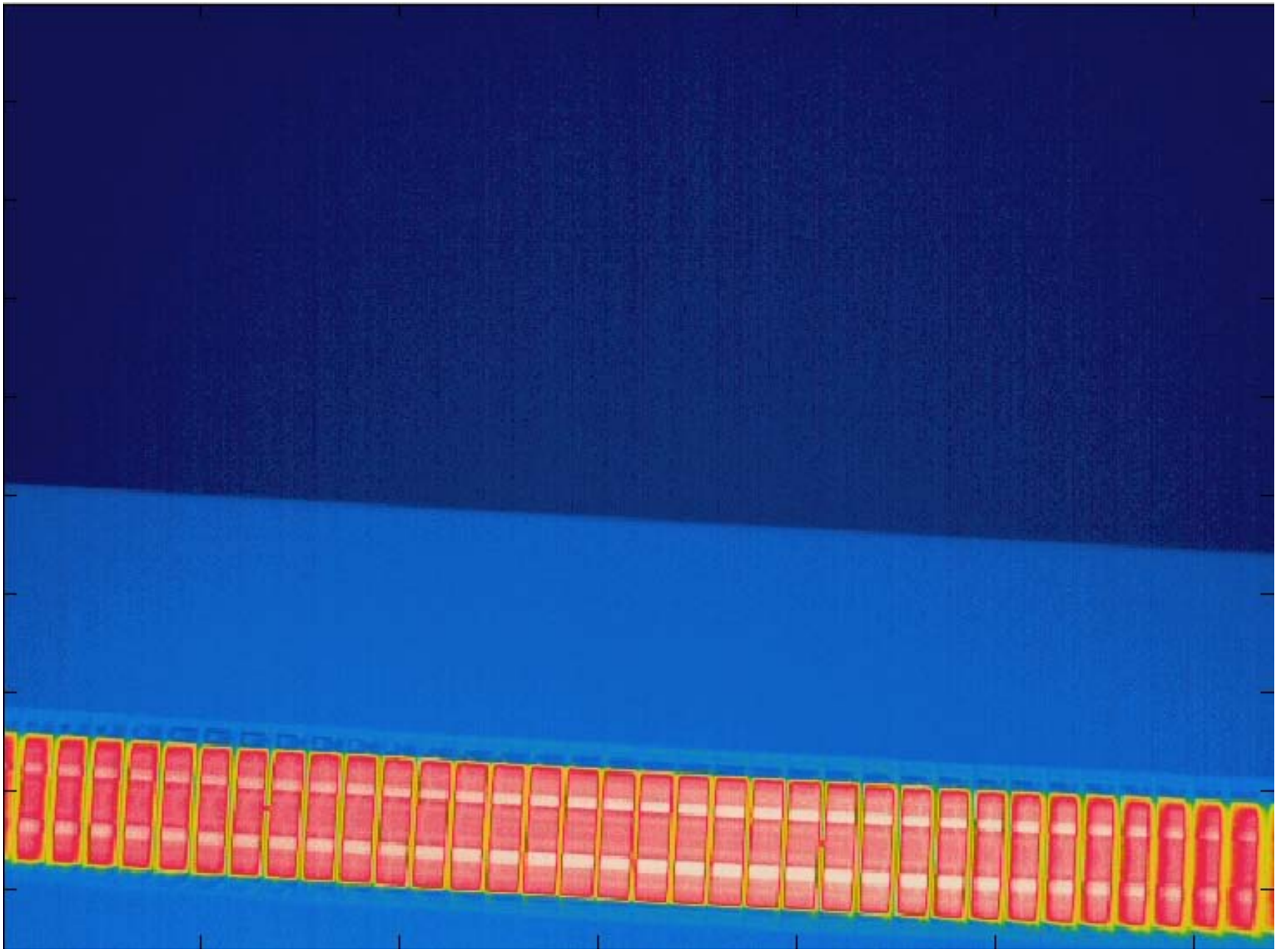
Traditionally: Bad pixel detection during production. Detected pixels stored in a special map with id of replacing pixels.

Ideally: Real time detection

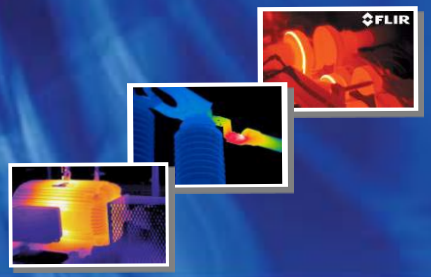
Object dependent replacement.

Single replaced pixels are difficult to se, clusters may be a problem.





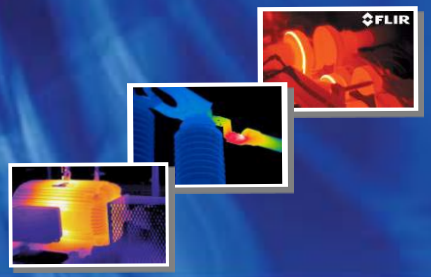
Noise



Cooled detectors	Usually very low noise
Uncooled	Heavy noise reduction necessary. Temporal, spatial and 1/f-noise. Often problems with correlated noise (row and column).

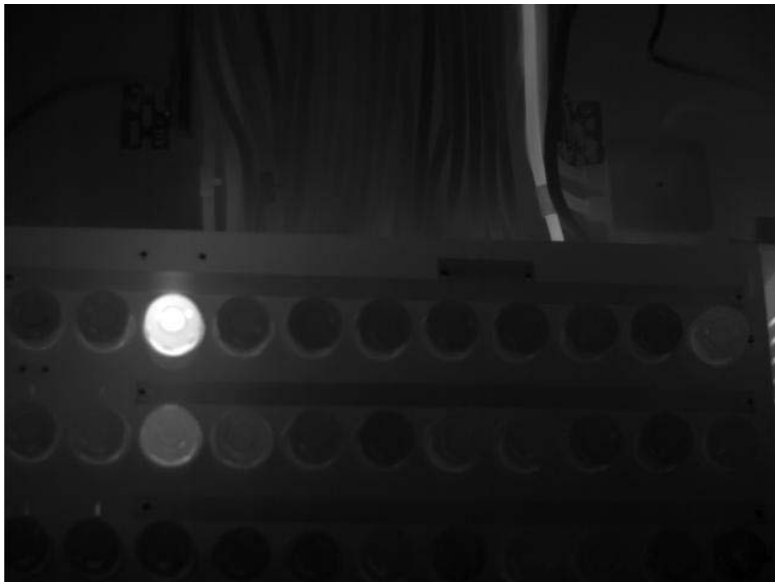
FLIR SYSTEMS
The Global Leader in Infrared Cameras

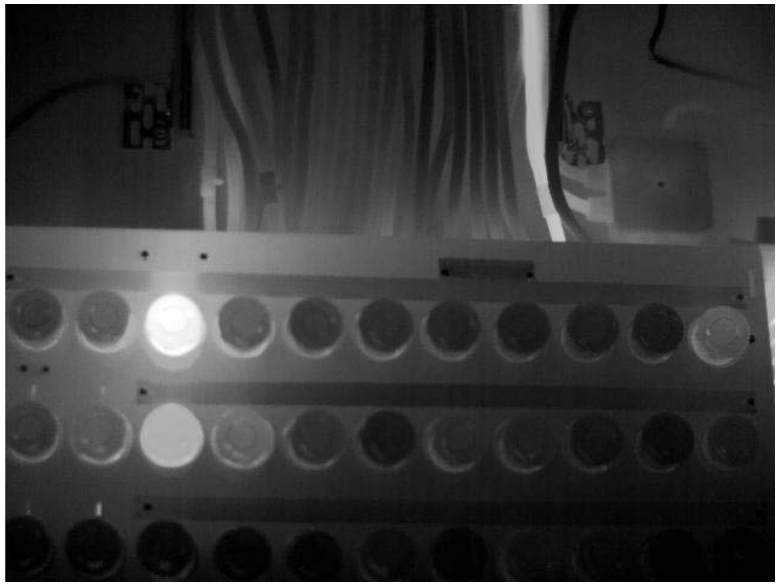
Colour



IR is monochromatic, the colour is artificial.

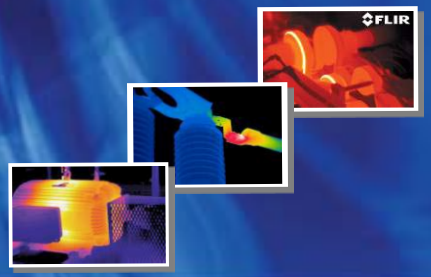
A non-linear colour palett is useful to enhance contrast.





FLIR SYSTEMS
The Global Leader in Infrared Cameras

Typical image defects



- Correlated noise
- Image non-uniformity
- Shadows
- Spots

Row and column noise

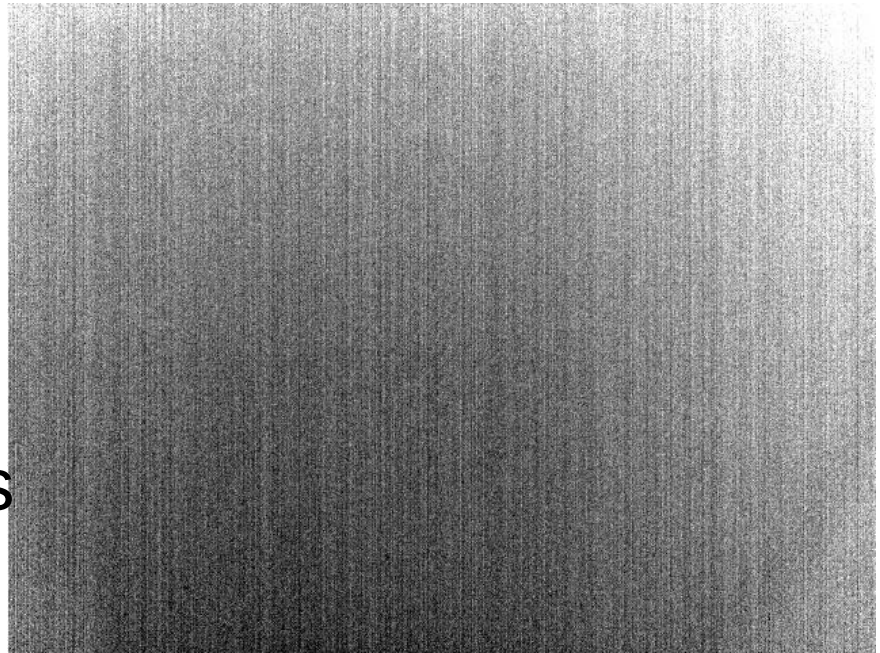
Disturbing row and/or column noise from all uncooled detectors. Often slowly temporal.

Reasons: Imperfections in detector read-out circuits (ROIC)

Solution: Live with it

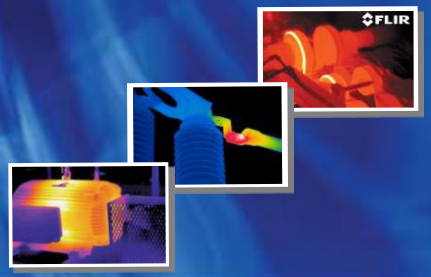
Digital filter

Blind bolometers



FLIR SYSTEMS
The Global Leader in Infrared Cameras

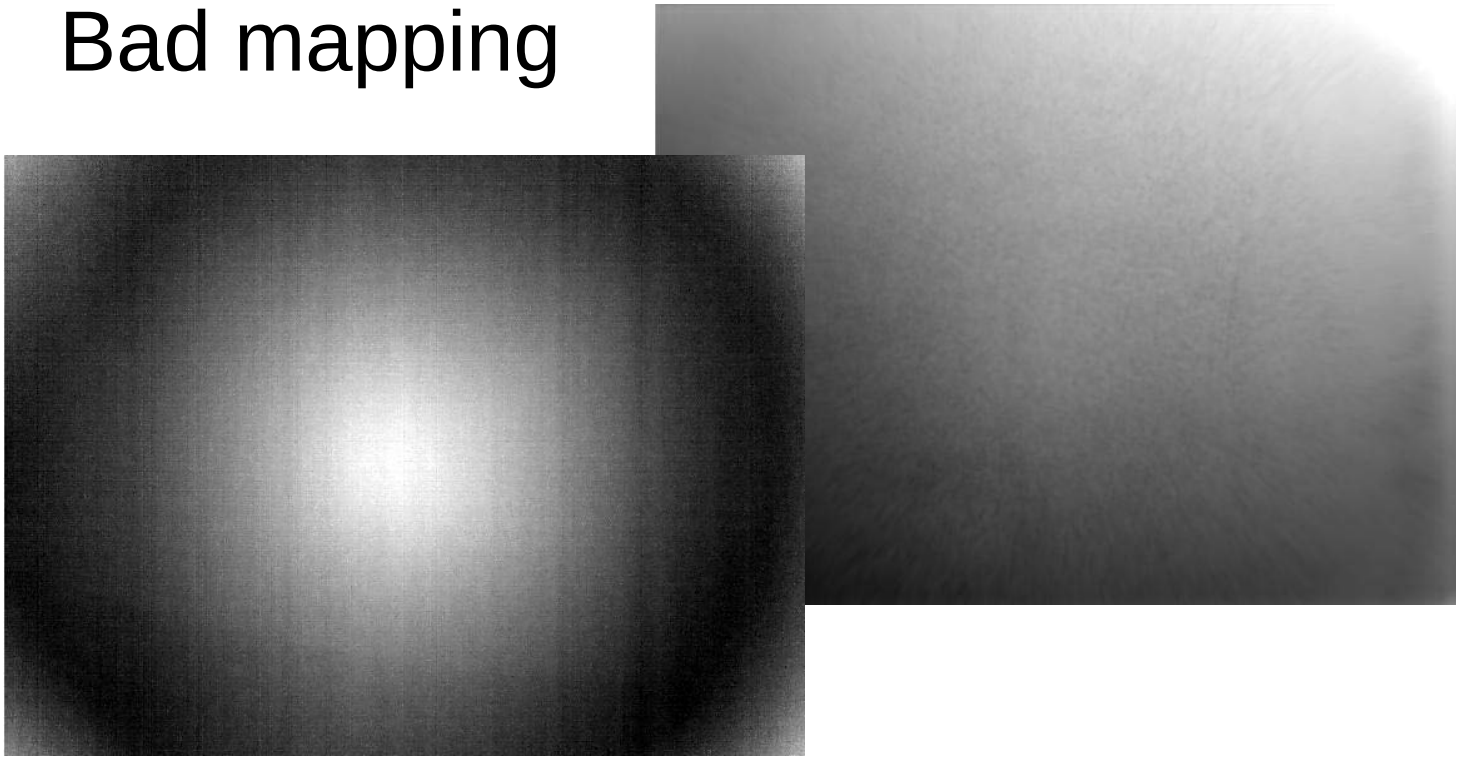
Image non-uniformity



Reasons: Mechanics

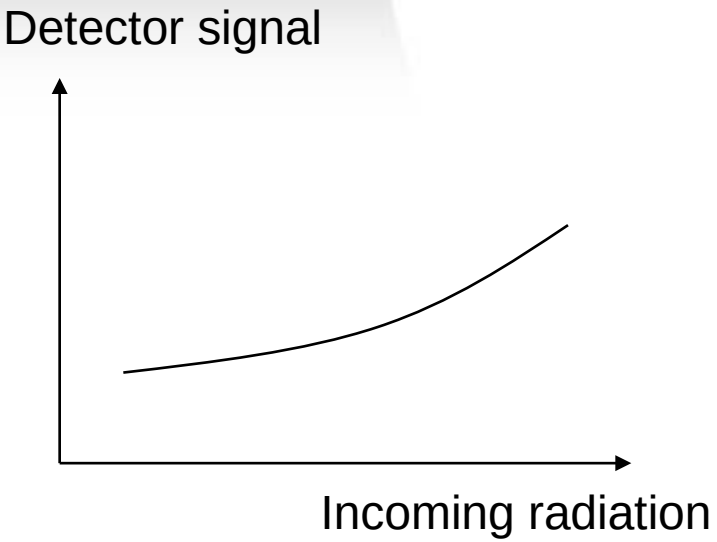
Bad optical design

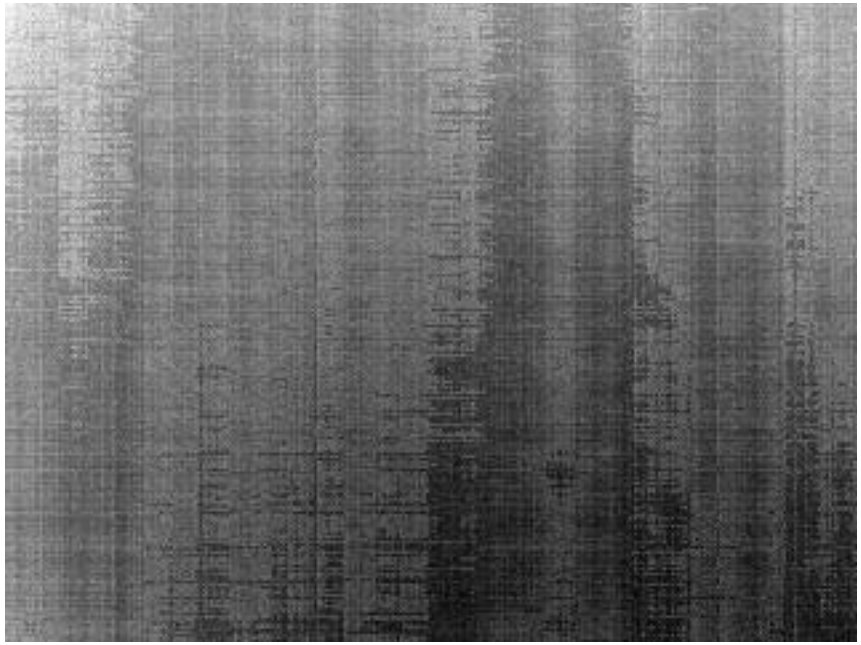
Bad mapping



Shadows

Reason: Nonlinear detector elements





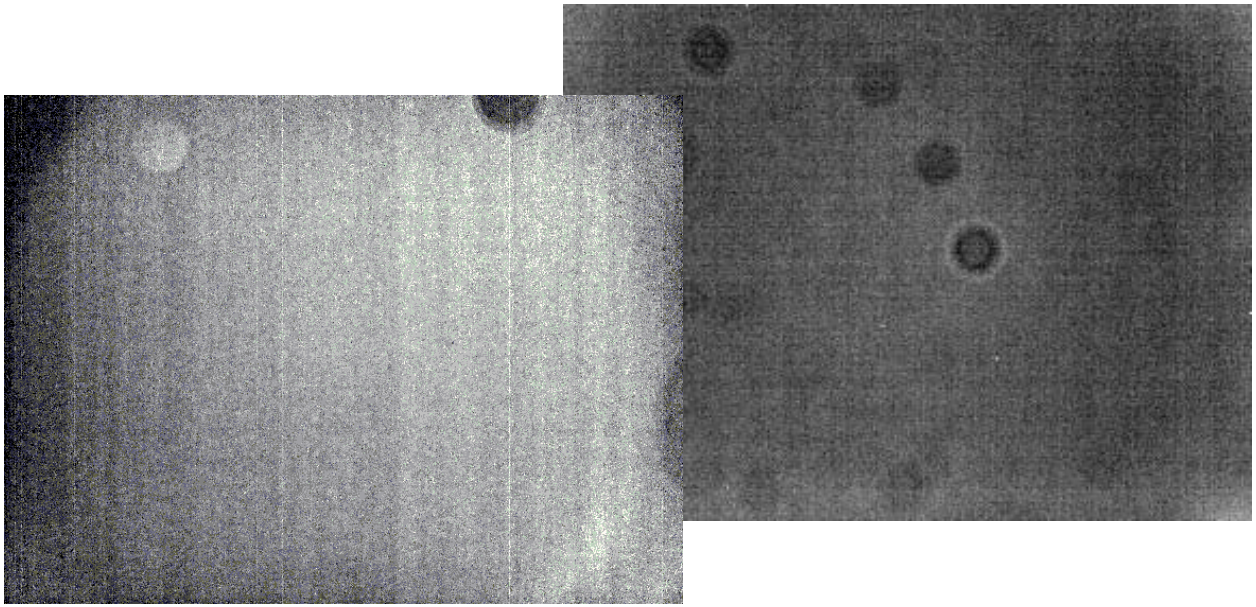
Solution: Usually nothing

Possible with advanced image processing

Spots

Reason: Dust om detector window

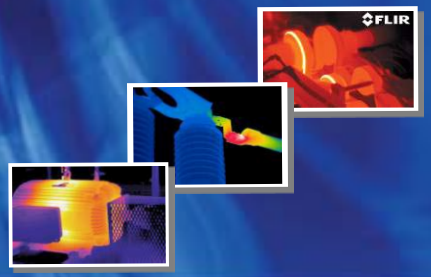
Imperfections in the anti reflection coating on the detector window



Solution: Keep the optics clean

FLIR SYSTEMS
The Global Leader in Infrared Cameras

Challenges with IR

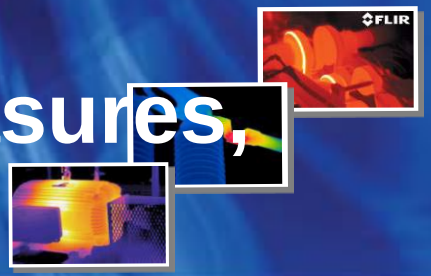


Compared to visual images:

- Low resolution
- Low contrast
- Noisy
- No texture
- No colour

FLIR SYSTEMS
The Global Leader in Infrared Cameras

Typical performance measures, uncooled



Detector resolution 640x480

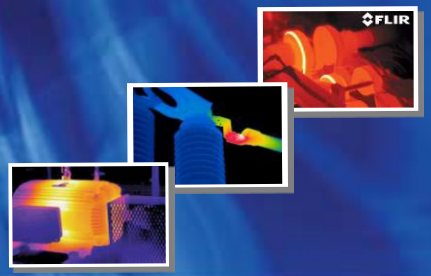
Detector element size 25 μm

Framerate 30 or 60 Hz

Temporal noise 30-40 mK

Measurement accuracy +-2 degree

Measures and features to compete with



Framerate

Resolution

Easy focus

Zoom lens

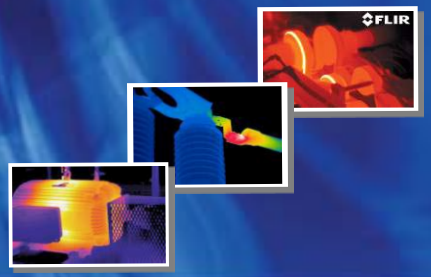
Features: Multifocus (Avio NEC)

Superresolution (Jenoptics)

Image fusion (Fluke, FLIR, ...)

FLIR SYSTEMS
The Global Leader in Infrared Cameras

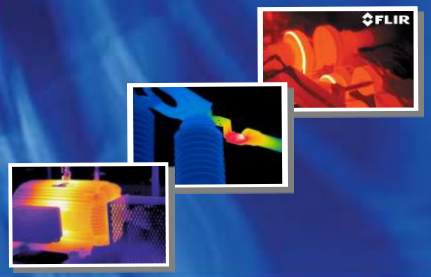
Data sheet NEC H2640



Specifications
Measuring range -40 to 500°C
Range 1: -20 to 60°C
Range 2: -40 to 120°C
Range 3: 0 to 500°C
Range 4: 200 to 2000°C (optional)
Resolution Range 1: 0.06°C or better at 30°C (30Hz)
Range 2: 0.08°C or better at 30°C (30Hz)
Range 3: 0.12°C or better at 30°C (30Hz)
Accuracy ±2°C or ±2% of reading, whichever is greater
Detector Uncooled focal plane array (microbolometer)
Spectral range 8 to 14µm
I.F.O.V. 0.6mrad
Focusing range 30cm to infinity
Field of view 21.7°(H) x 16.4°(V)
Frame time 30 frames/sec
Display View finder & 5.6-inch movable color LCD
Thermal image pixels 640 (H) x 480 (V) pixels
Emissivity correction Provided (0.10 to 1.00)
Ambient compensation Provided
Background comp. Provided

FLIR SYSTEMS
The Global Leader in Infrared Cameras

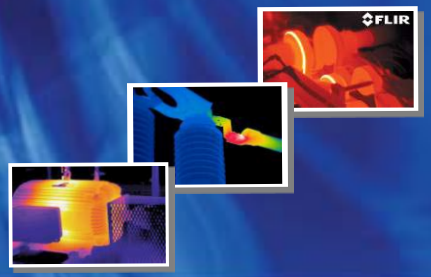
Data sheet (cont.)



Auto functions Full automatic (level, sense, focus)
Isothermal band display Provided (up to 4 bands)
Image processing functions Thermal/visual image fusion display
Multi-point temperature display (up to 10 points)
BOX setting, up to 5 boxes (max, min, average)
Temperature difference between 2 points (Δt)
Visual camera 1.3M pixels, color
Laser pointer
Class 2 (1mW or lower, red)
Video signal output NTSC/PAL, composite video signal, S-video
Interfaces IEEE1394
USB2.0
Compact flash mermory card slot
Operating temperature - 15 to 50°C
Shock and vibration Shock: 294m/sec2 (30G) (IEC60068-2-27)
Vibration: 29.4m/sec2 (3G) (IEC60068-2-6)
Environmental protection IP54 (IEC60529)
Dimension & weight Approx. 110 (W) x 110 (H) x 210 (D) mm
(excluding projections)
1.7kg (including battery)
Standard accessories AC adaptor, battery pack (2 pcs), battery charger,
compact flash mermory card (1GB), compact flash
memory card adaptor, carrying case, grip belt,
neck strap, lens cap, viewer software, operation
manual, USB cable, target illuminator

FLIR SYSTEMS
The Global Leader in Infrared Cameras

Expected development



- Decreasing detector prices due to rising volumes
- Increasing volumes due to falling detector prices
- Smaller, lighter cameras
- More built-in-functions
  - Communication
  - Usability
  - Image processing