2022 Technical Report

IRAY Micro III Camera Performance Analysis

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Introduction

- Thanks to multiple drivers, the market for infrared thermal imaging cameras and modules is expanding rapidly, with a multiplicity of products on offer. There is, therefore, a need for users, integrators, and sensor manufacturers to be able to discriminate between available products based on accurate and independent assessments of their performance and features.
- This report is the fourth of its kind, focused on helping thermal imaging camera and module market actors to better understand the characteristics of such products, enabling better strategic decision-making.
- More reports will follow soon, which will allow fair comparisons of product features and performance.
- The following cameras and modules have either already been analyzed or are planned:
  - InfiRay T3S camera module: published
  - Flir Boson 640 Pro camera (USA): published
  - Seek thermal module QVGA 12µm (USA): published
  - Comparison of camera performances Infiray T3S, Flir Boson 640, Seek thermal QVGA, Infiray Micro III (planned July 2022)
  - GuideIR VGA 12µm (China): planned
  - Hikvision camera QQVGA 17µm (China): planned
  - Teledyne Dalsa GXF (Canada): planned

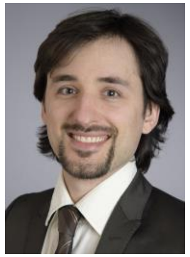
Objectives of This Report

- This report aims to provide a comprehensive and independent analysis of the main features, performance, and imaging system architecture of the Iray Micro III Camera Core.

- Our analysis is based on physical measurements, calculations, simulations, and observations realized in PISEO's lab, compared to data provided in the datasheet.

- This report presents:
  - An analysis of the user functions of the camera.
  - An analysis of the measured performance parameters of the embedded microbolometric sensor.
  - An analysis of the measured thermometric performance and optical architecture of the camera.
  - An analysis of the sensor correction functions and algorithms.
  - An analysis of the image processing flow from sensor to image, as well as an assessment of image quality.
  - Our opinion of the camera's features and performance.
  - A fair comparison of the product's performance against other marketed products.

Authors of This Report



Grégory Duchêne - Sr Optical Designer, illumination, detection and imaging systems - PISEO

Grégory Duchêne is in charge of advanced optical systems studies and analyses at PISEO. He has an engineering degree from the Institut d'Optique Graduate School (IOGS). Grégory has successfully designed the optics of many innovative photonic systems for PISEO's' customers. In addition to his strong optical design skills, he has in-depth know-how of optical metrology of illumination and imaging systems. Grégory is our Zemax expert and also teaches optical system design at IOGS.

Dr Olivier Andrieu – Innovation Leader and System Architect - PISEO

Olivier ANDRIEU is in charge of technical expertise and innovation projects at PISEO. He has a degree in engineering and a Ph.D. in physics from the INPG Graduate School. His career has allowed him to carry out various responsibilities in innovation in the automotive sector in connection with sensors and battery management systems, as well as within Philips Lighting, where he acted as a system architect. Olivier has supervised the design of numerous photonic systems for different sectors, which have been commercialized. He has also performed many technical analyses of photonic systems and published several reports in collaboration with Yole Développement's teams.

Lionel Artinyan – Photonic Systems Test Engineer - PISEO

Lionel Artinyan has an engineering degree from the ENSSAT Graduate School and has a strong background in photonic component and system characterization. At PISEO, Lionel is in charge of custom test bench engineering and test realization. He has participated in the design of many different test benches that include optical devices and control programs. Lionel has successfully tested many systems that integrate pulsed light sources, such as xenon lamps, LEDs, and laser diodes, as well as imaging sensors.

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Select a chapter to access it

Glossary

- ACE — Adaptative Contrast Enhancement
- AGC — Automatic Gain Correction
- BiCMOS — Bipolar CMOS
- CMOS — Complementary Metal Oxide Semiconductor
- DN — Digital Number
- DNS — Deep Noise Supression
- DDE — Digital Detail Enhancement
- DRC — Dynamic Range Compression
- FFC — Flat Field Correction
- FOV — Field-of-View
- FPA — Focal Plane Area
- FPGA — Field-Programmable Gate Array
- GUI — General User Interface
- IBE — Information-Based Equalizer
- INU — Image Non-Uniformity
- MRTD — Minimum Resolvable Temperature Difference
- MTF — Modulation Transfer Function
- NETD — Noise Equivalent Temperature Difference
- NUC — Non-Uniformity Correction
- NVFFC — Non-Volatile Flat Field Correction
- PSF — Point Spread Function
- RFPN — Residual Fixed Pattern Noise
- ROI — Region of Interest
- ROIC — Read-out Integrated Circuit
- SCNR — Spatial Column Noise Reduction
- SDK — Software Development Kit
- SEM — Scanning Electron Microscopy
- SFFC — Supplemental Flat Field Correction
- SRNR — Spatial Row Noise Reduction
- SSN — Silent Shutterless NUC
- UAV — Unmanned Aerial Vehicle
- USB — Universal Serial Bus
- UVC — USB Video Class
- VOx — Vanadium Oxyde

Micro III Camera Presentation

Portfolio

- The Micro III camera from InfiRay is a compact LWIR thermal camera module, available in different versions.
- The camera integrates a 12µm-pitch vanadium oxide uncooled detector available in two pixel sizes: 640x512 px (VGA) and 384x288 px (QVGA).
- The module includes image processing capabilities and standard communication interfaces.
- It is targeted at industrial and military applications:
  - UAVs for surveillance, crop, or site inspection…(the Micro III camera's lightness is quite convenient for embedding as a payload in a UAV).
  - Many other applications, such as monitoring and thermography.
- Each module is equipped with a lens with a specific FOV and depth-of-field range. The variety of lenses (eight options for each size) covers various FOVs. No information on FOV values has been obtained from the manufacturer.

picture source: InfiRay

Technical Characteristics

Overview

- The main technical information is presented on a one-page datasheet, subdivided into major items :
  - Global specifications related to sensor properties : technology, sensor resolution, pixel pitch, sensor sensitivity or NETD, frame rate, etc.
  - Optical & Mechanical, which details the various possible configurations.
  - Thermography.
  - Environmental.
- This kind of information is standard amongst uncooled thermal sensor manufacturers. Cameras in the two categories (T & TH) are probably selected through a binning process during a final test of the sensor after manufacture.
- The camera tested was a 384 x 288T version (NETD <50mK).

Model	Temperature Measuring		High Precise	
	Micro Ⅲ 640T	Micro Ⅲ 384T	Micro Ⅲ 640TH	Micro Ⅲ 384TH
Performance Specification				
Detector	VOx uncooled thermal FPA			
Resolution	640×512	384×288	640×512	384×288
Pixel size	12μm			
Frequency	25Hz	50Hz	25Hz	50Hz
Response spectrum	8~14μm			
NETD	≤50mK@25℃		≤40mK@25℃	
Thermal Image				
Brightness and Contrast	Manual/Auto			
Palette	Upto 18 palettes			
Reticle	Display/Fade/Move(Support for Customization)			
Zoom	1.0~8.0× Digital Zooming (0.1×Step)			
Image Filter	Digital Noise Reduction / Digital Detail Enhancement			
Power Supply				
Power Supply	4~6V DC			
	5~24V DC with User extension component			
Power Protection	Over voltage, Under voltage, Reverse connection protection(with user extension component)			
Typical Power Consumption @25℃	<1.0W (without user extension component)	<0.9W (without user extension component)	<1.0W (without user extension component)	<0.9W (without user extension component)
	<1.2W (with user extension component)	<1.1W (with user extension component)	<1.4W (with user extension component)	<1.4W (with user extension component)
Connection Interface				
Video Output – Analog video	1 channel PAL or NTSC			
Video Output – Digital video	BT.656/14-bit or 8-bit LVCMOS/LVDS/MIPI/CameraLink			
Serial Port	RS-232/UART (3.3V)			
USB3.0	5V Typical, Image and Temperature data transmission, device control			
Temperature Measurement				
Measurement Range	-20℃~+150℃, 0℃~+550℃		0℃~60℃	
Measurement Accuracy (1)	±0.3℃ or ± 3% of Reading (Take Lager)@ Environment Temperature-20℃~+60℃		±0.5℃@Target Temperature of 33℃~42℃ (±0.3℃ with blackbody)	
Measurement Tools	10 spots / Max & Min temp on Screen/ Center spot/12Lines/ Area Analysis/1 Isothermal Analysis			
SDK				
Customiztion Support	User Language/Crosshair Customiztion			
SDK	Support			
Physical Character				
Weight	20g±3g (without lens & user extension component)			
Size	26×26×22 (mm) (without lens & user extension component)			
Environmental Adaption				
Operating Temp	-40℃~+80℃		-10℃~+50℃ (16℃~32℃ High Precise)	
Storage Temp	-45℃~+85℃			
Humidity	5~95%, non-condensing			
Vibration	6.06g, Random vibration, all axes			
Shock	80g, 4ms, back peak, sawtooth wave, 3-axis and 6-direction			

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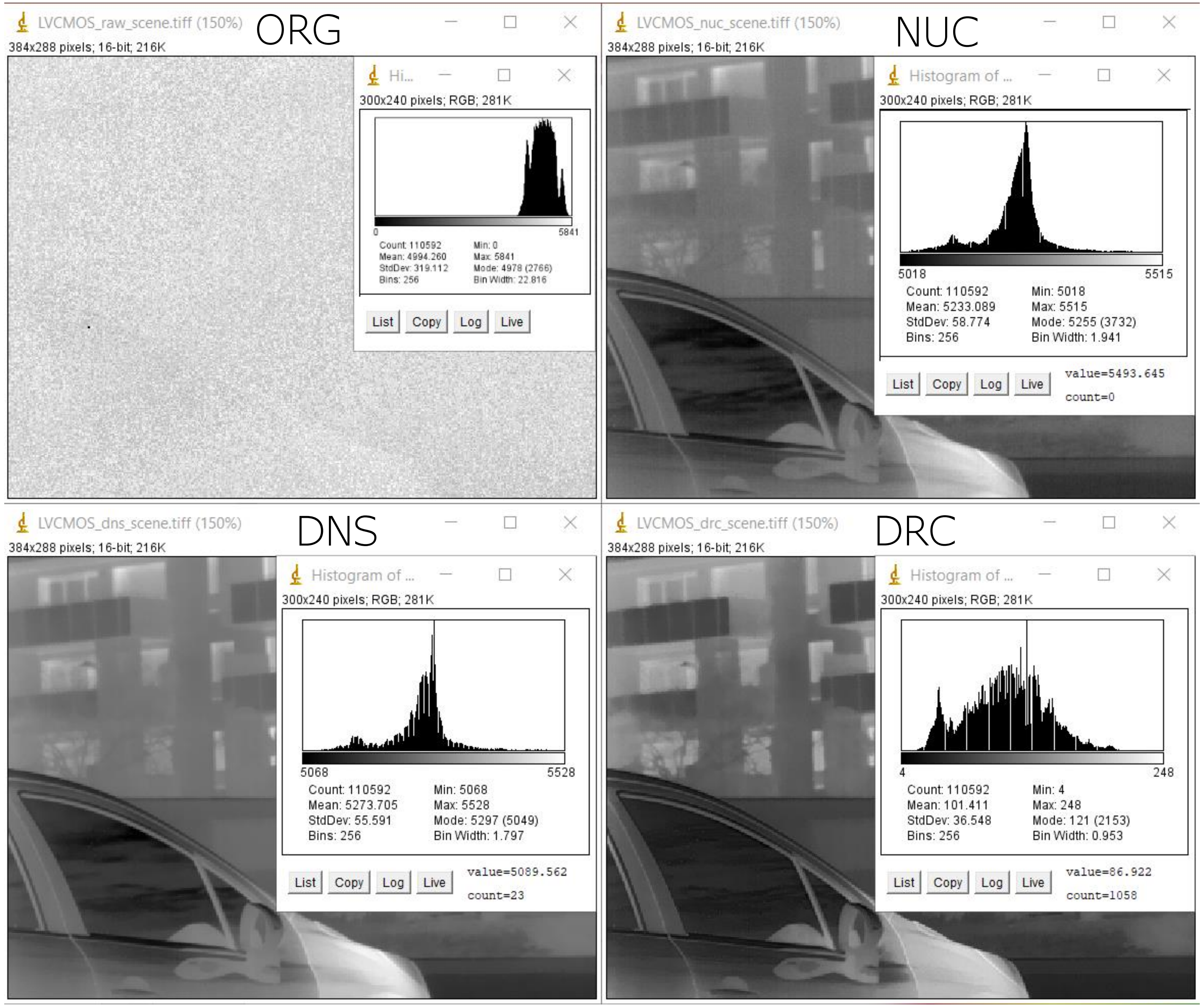
GUI Functionalities – Video Source

- ORG mode can be assimilated to a RAW mode.
- From NUC to DNS to DRC modes, the image appears more accurate and sharper.
- Detailed analysis in chapter, 'Micro III Correction Function'.



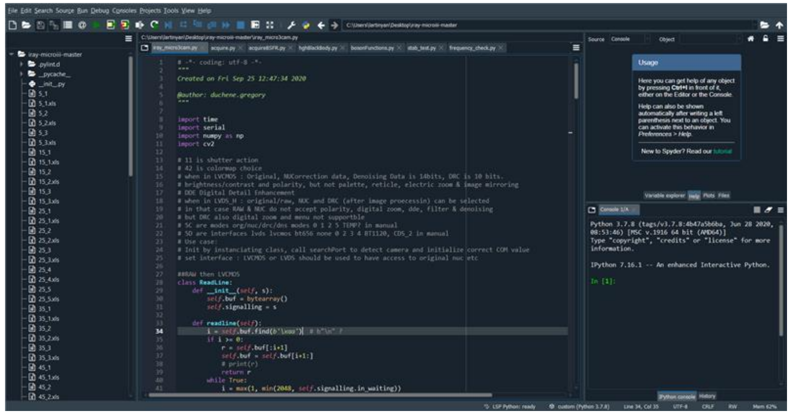
source: PISEO

Image Sensor Characterization

Methodology

Procedure used to retrieve images during image processing

- Images produced by the sensor are retrieved at different processing stages or pipeline taps:
    - Raw image for bolometric sensor characterization.
    - Images after other process steps, in order to analyze and qualify the image processing offered by the camera.
- PISEO's interface software was built from observation of the camera communications, as no SDK was provided by InfiRay.



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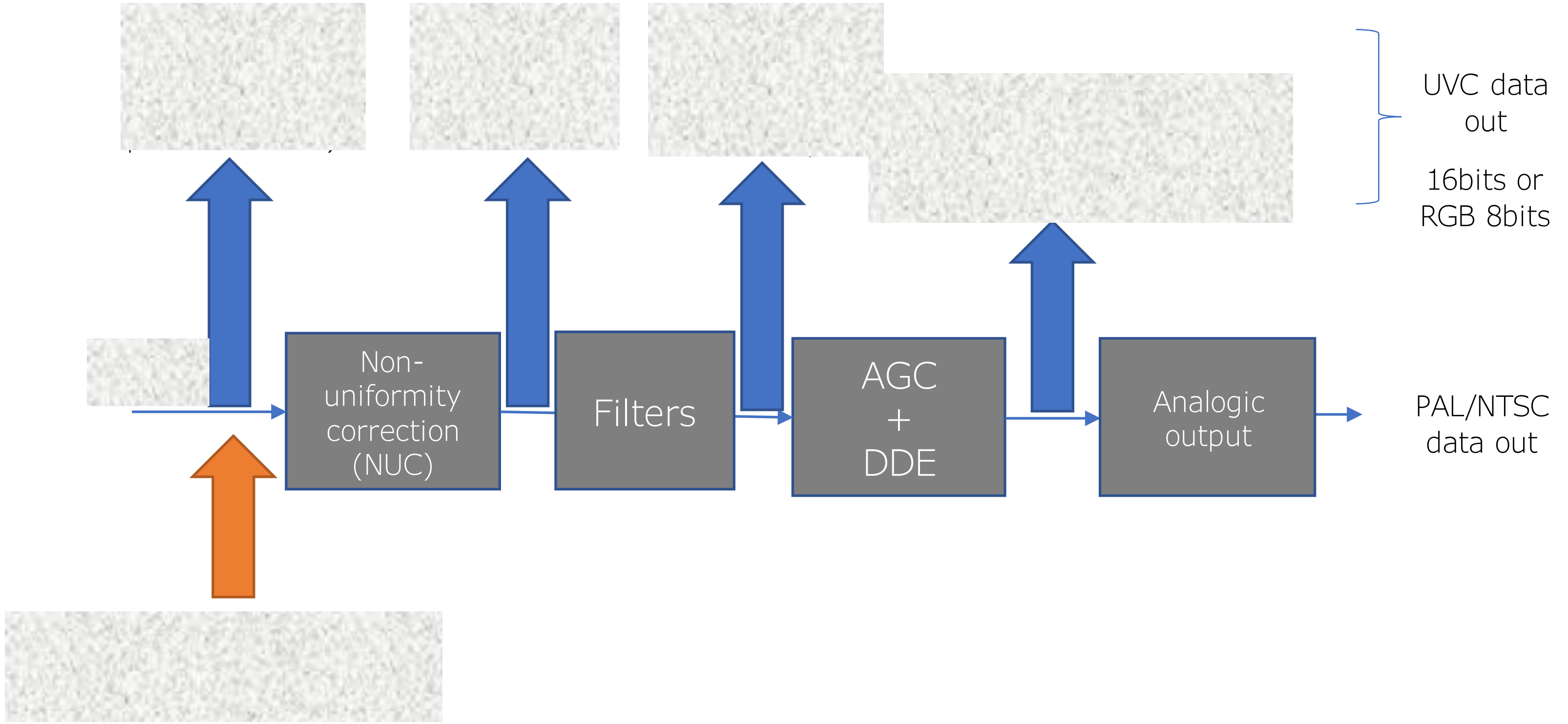

Blackbody Setup

Methodology

Uniform and controlled temperature with a blackbody

- A controlled-temperature scene is placed in the field of view of the camera:
  - Represented by a blackbody (HGH) regulated temperature surface
  - Possible to control the surface temperature from -15°C to +150°C
  - Accurate control of the scene temperature: < +/-0.03 °C
  - Temperature uniformity across the surface: 0.01 °C @25°C, 0.3°C @ 50°C
  - Stability 0.5mK
- Climate chamber for ambient temperature control:
  - 0°C to 50°C

Typical IR camera test set-up @PISEO's lab

source: PISEO

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Responsivity / NETD / Scene Dynamic

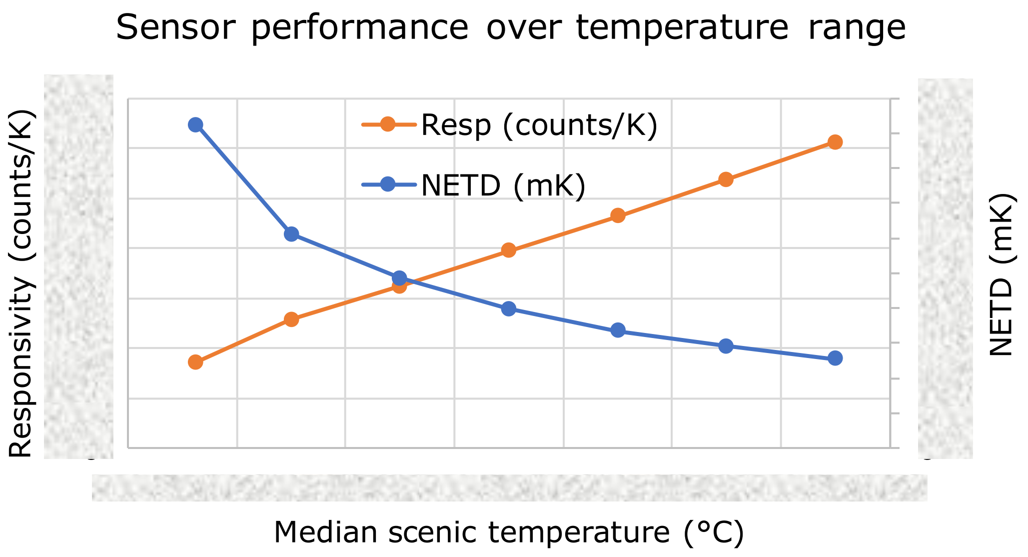
Characterization

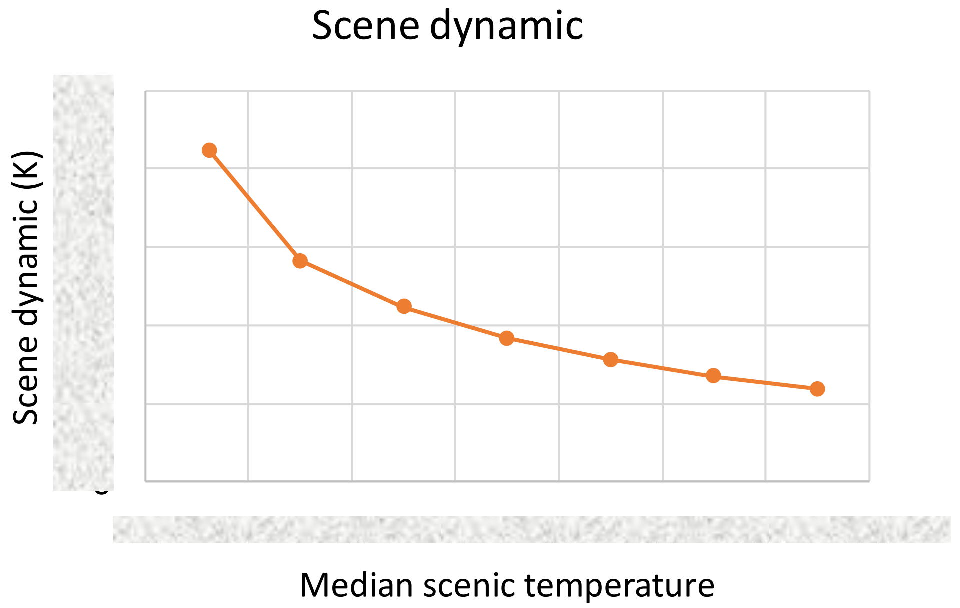
Extended scenic temperature 20°C to +100°C

- The responsivity increases with the blackbody temperature. Temporal noise remains stable, so NETD decreases when the temperature of the scene is high. In the other way, NETD is higher for colder scenes.
- While the responsivity increases, the scene dynamic decreases.

T1 (°C)	-15	0	20	40	60	80	100
T2 (°C)	0	20	40	60	80	100	120
T NETD (°C)	25	25	25	25	25	25	25

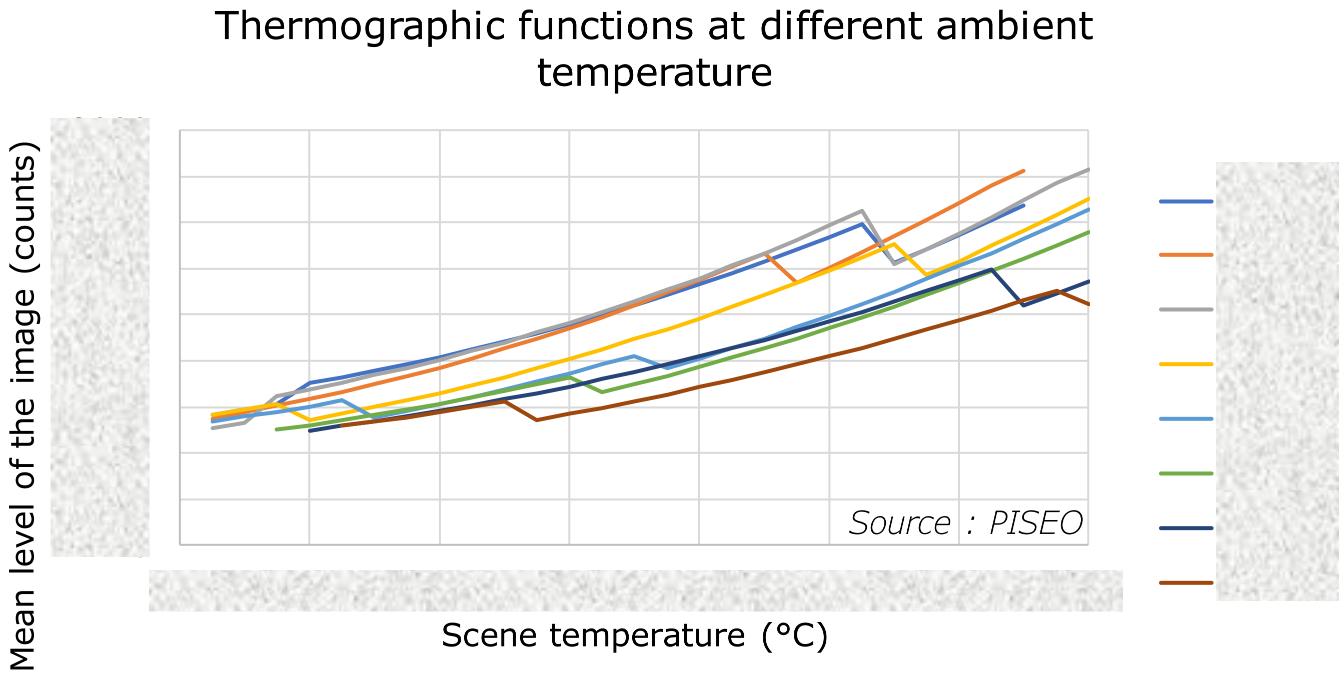
Resp (counts/K)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NETD (mK)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Scene dynamic (K)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]





Thermographic Response

- These curves reflect the calculation of the responsivity, the scene dynamic parameters, and the behavior with ambient temperature.
- The pixel response (here, a mean value of a uniform scene) falls largely in the [redacted] digital output scale, providing flexibility for image processing steps.
- The measuring temperature range of the camera is [-20°C ; +150°C]. We performed our tests in the range [redacted], which covers most of the operating range.
- Offset at random intervals appears on these curves, preventing a good thermographic calibration:
    - [redacted]
    - [redacted]
- [redacted]



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Measurement Tools	10 spots / Max & Min temp on Screen/ Center spot/12Lines/ Area Analysis/1 Isothermal Analysis			

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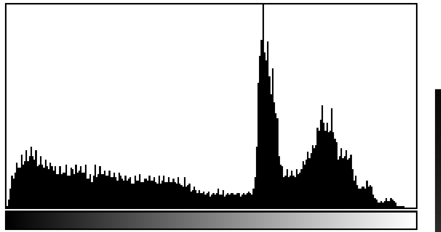
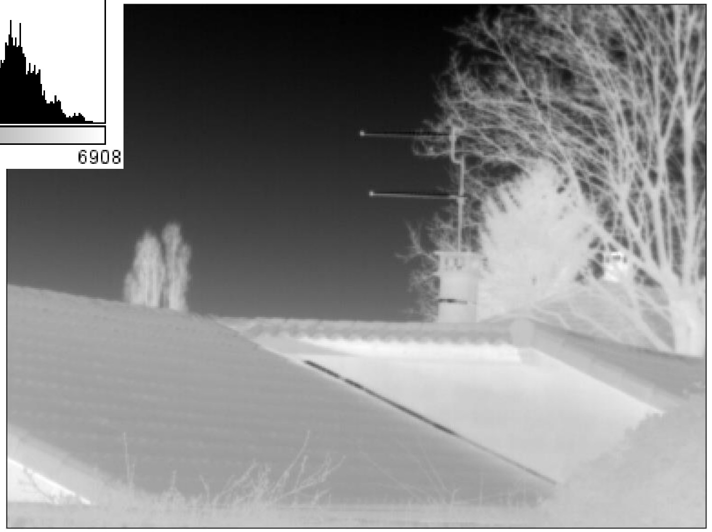
NUC Performance

NUC resulting effect

- Non-uniformity correction is performed as in these examples:
  - By the camera, based on factory-calibrated gain & offset tables and a shutter map obtained a few seconds before.
  - By PISEO, based on uniformity calibration performed on a blackbody a few minutes before.
- In spite of the difference in non-uniformity metrics presented on the last slide, both images reveal equivalent defects which cannot be suppressed by NUC only. These defects justify the application of spatial and temporal filtering, described and analyzed in the next chapter.
  -
  -

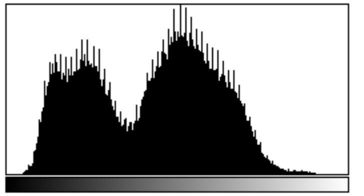




Iray NUC

Iray raw

PISEO NUC

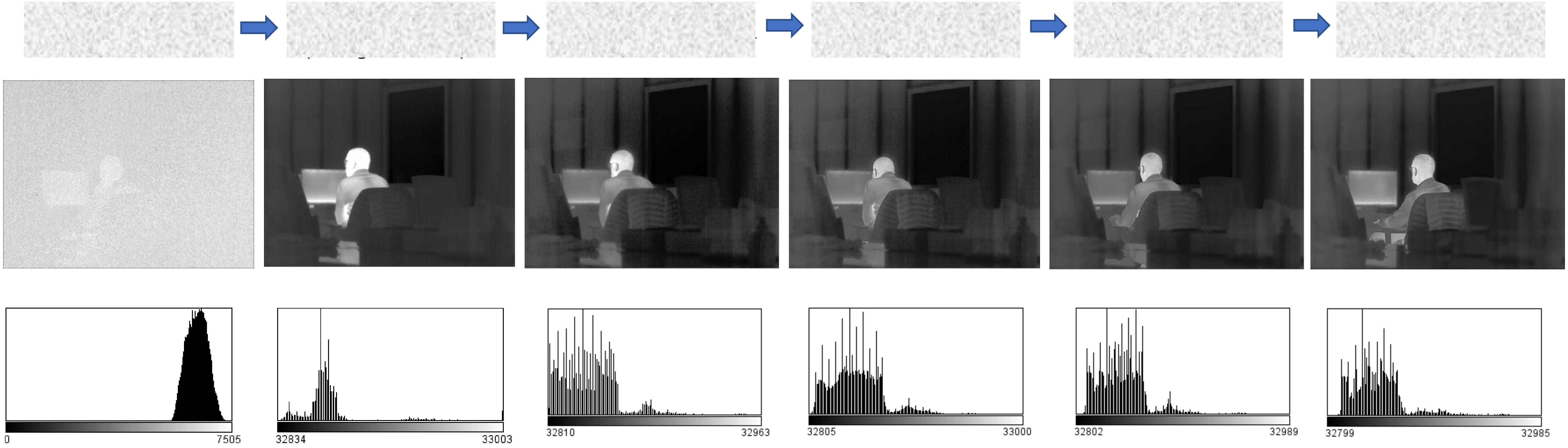


source : PISEO

NUC Channel

NUC processing: flow chart

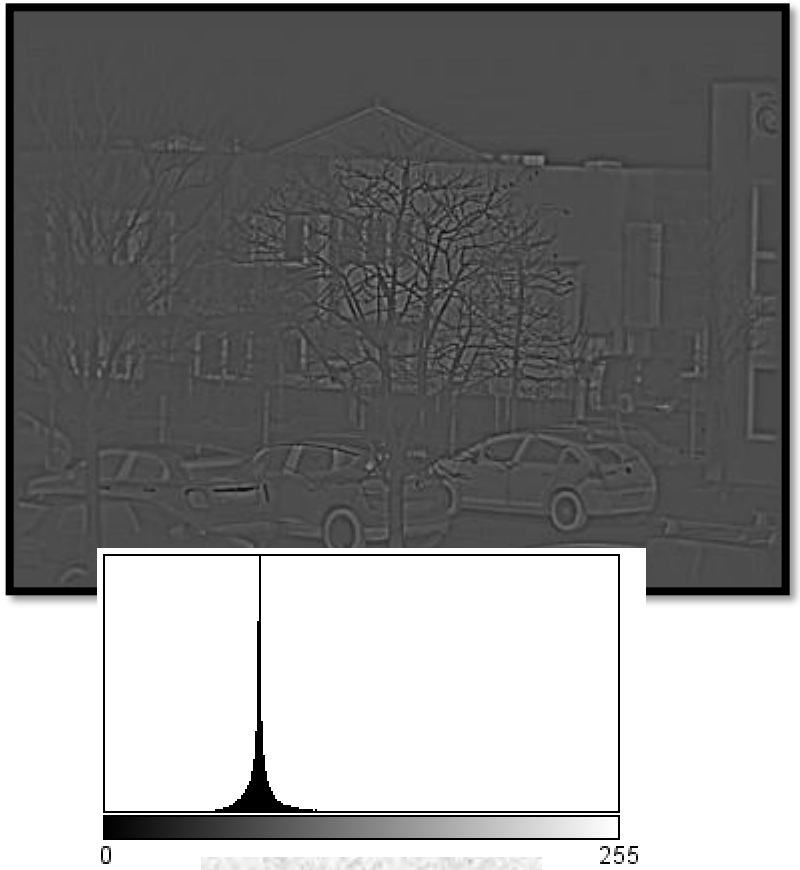
- The flow chart below illustrates the benefits of the succession of correction steps.
- The FFC (flat field correction) is obviously the most impactful step. However, other filters can still enhance edge detections, smoothing, or different ranges of temperatures.
- When it is possible to be applied, the SFFC (supplemental FFC) does improve the uniformity and eliminates the lens defects observed on the test sample. Compared to the standard factory correction maps, this function has the capacity to correct optical defects, due either to the application use-case or the time evolution of the camera. However, this function is only available in a hidden menu of the software.



images source: PISEO

AGC

Contrast



source: PISEO

- Contrast can be adjusted, keeping constant the mean value and moving the width of the allowed range. Histogram is enlarged.

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ABOUT PISEO

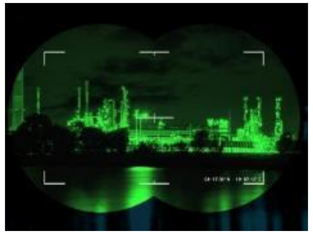
- An Independent Innovation Center specializing in the integration of advanced photonic technologies.
- Supports companies in all sectors of activity in the analysis, design, and characterization of innovative illumination, detection, and visualization systems.
- Experience gained from large industrial groups.
- Created in November 2011 as part of the French State Call for Projects for shared innovation platforms.
- Eight industrial shareholders including Yole Développement, GIL-Syndicat du luminaire, Syndicat de l'éclairage, Serma Group, and Cluster Lumière.
- Based in Lyon, France.
- 150+ clients (large groups, ETI, SMEs, start-ups).
- CIR, CII, and EASYTECH approved.
- Accredited lab (scope @ www.cofrac.fr).
- 17 employees.

OUR MARKETS

Automotive Aeronautics Railway



Security Defense



Imaging



General Lighting



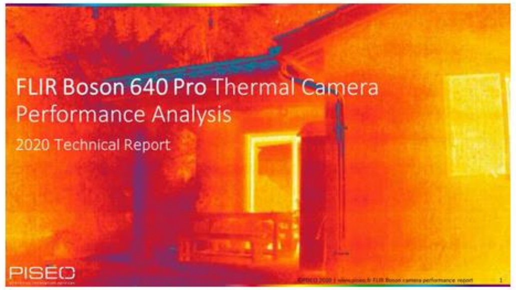
Health Care Well-Being



Telecom Processes Watchmaking

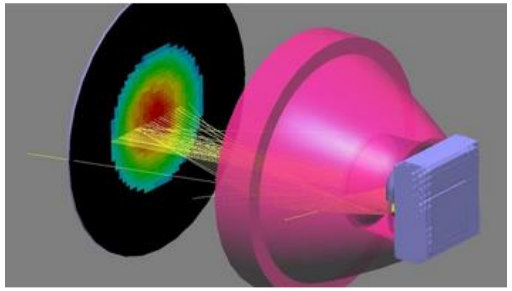


OUR SERVICES AT COMPONENT AND SYSTEM LEVEL



Application and technical analyses

- ✓ Reverse engineering
- ✓ Performance analysis
- ✓ Application and technical reports
- ✓ Benchmarking of component and system performance and construction
- ✓ Regulatory and normative intelligence
- ✓ Technology intelligence
- ✓ Patent intelligence



System design and realization

- ✓ Application requirements of photonic systems (UV, VIS, IR)
- ✓ Concept generation
- ✓ Feasibility studies
- ✓ Optical, mechanical, electronic, and software design
- ✓ Simulations
- ✓ Thermal management
- ✓ System integration
- ✓ Prototyping, assembly, pre-series, and small-volume production with partners
- ✓ Redesign to cost, to quality
- ✓ Design for reliability

Characterization and test laboratory

- ✓ Photometric and colorimetric measurements (accredited)
- ✓ Spectral and radiometric measurements (UV, VIS, IR)
- ✓ Photobiological and laser risk assessment (accredited)
- ✓ Luminance and color maps of displays, light panels, etc.
- ✓ Electrical measurements
- ✓ Temperature measurements
- ✓ Characterization of cameras, modules, and imaging sensors (VIS, IR): NUC, NETD, responsiveness, MTF…
- ✓ Materials: reflectance, transmittance, spectral analysis, BRDF…

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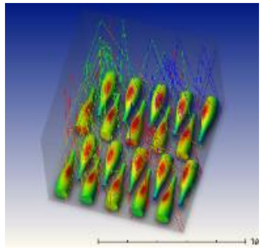
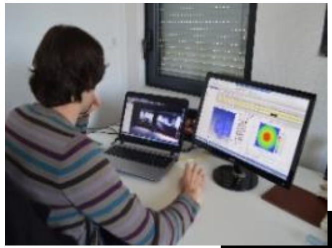
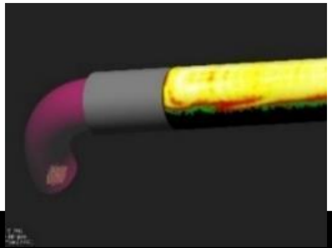
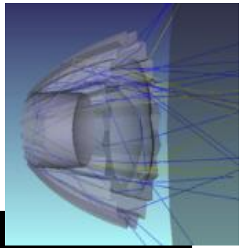
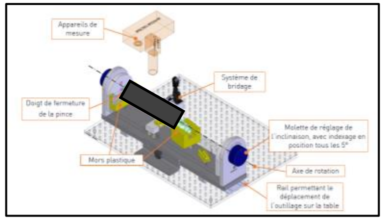
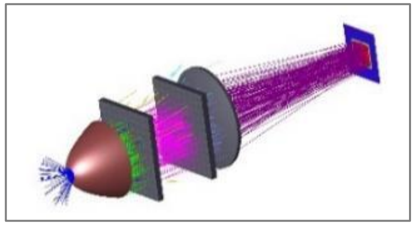
OUR TECHNICAL PLATFORMS

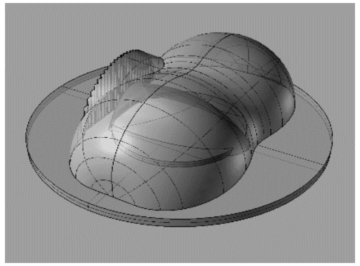
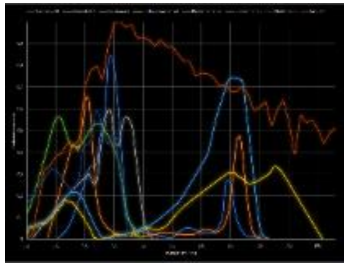
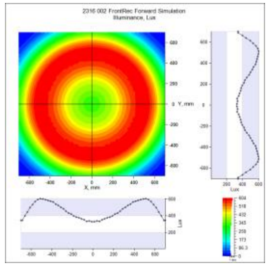
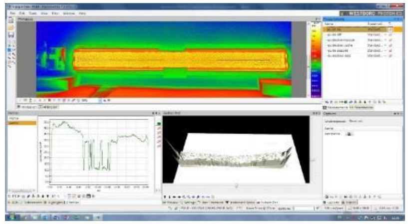
Design and analysis tools

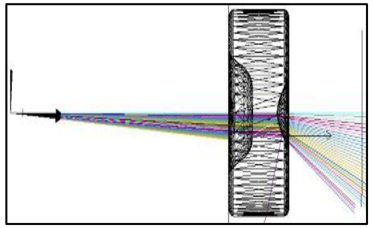
- Patent pulse
- Proprietary physical models
- Zemax Optics Studio 20 & Premium (2x)
- LightTools 9 (3x)
- Radiant Imaging Prosource
- Rhino 3D
- Solidworks
- Python, C ++, Arduino, Labview programming
- Algorithmics
- Three computing stations, 24 cores, 3.1 GHz
- Network of partners in electronics, mechanics, integration, and assembly





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OUR TECHNICAL PLATFORMS

Testing laboratory

- Goniophotometer LMT C-Type GO 2000
- Integrating spheres Instrument Systems 2m & GL Optik 50cm
- Instrument Systems Spectroradiometers CAS 120 (VIS), CAS 140CT (VIS), CAS 140D (300nm-1100nm)
- BTS256-EF Gigahertz Optik Spectrophotometer-Colorimeter
- Westboro Photonics PF 501A 5Mpx video luminance meter
- Radiometric bench Everfine OST 300 (200nm-1600nm)
- Power probes and integrating sphere (200nm-1100nm)
- Infratek Variocam thermal camera
- Blackbody HGH DCN 1000H4
- YOKOGAWA WT 3000 power meters
- Stabilized and central power supplies: Chroma, TTi, Keithley…
- Partner network (Serma Technologies, labs, etc.)

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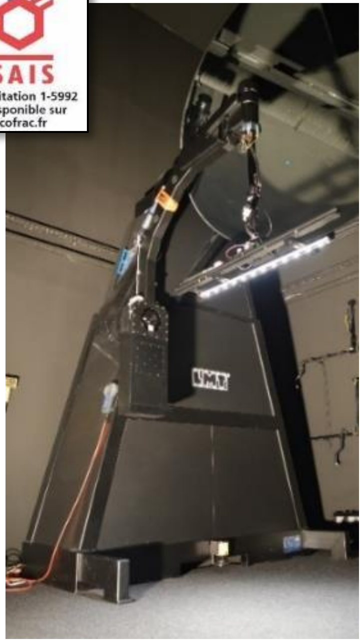
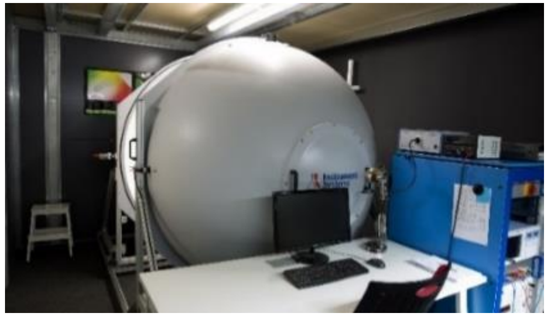
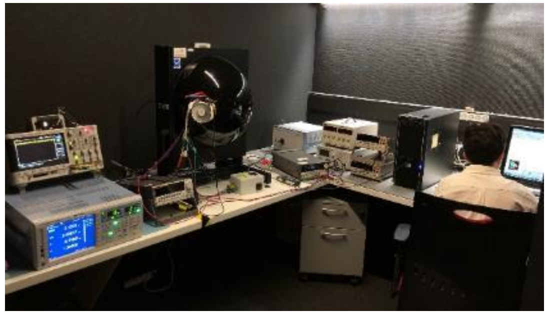
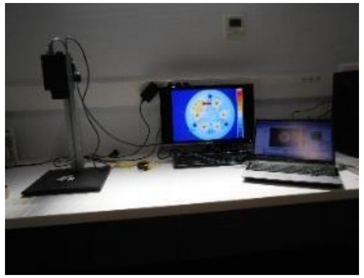

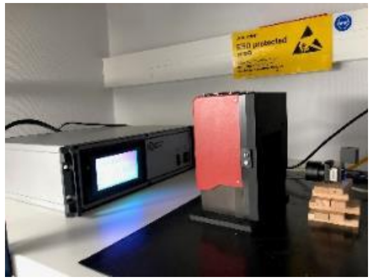

WHAT CHARACTERIZES US?

- 250+ customer projects and 5,000+ tests carried out.
- Unique combination of expertise and high-level technical means in the design and characterization of illumination, detection, and imaging systems.
- Very diverse industrial experience.
- Applied and multi-physics approach of integrated systems.
- Network of leading partners.
- Agility.
- Independence and impartiality.

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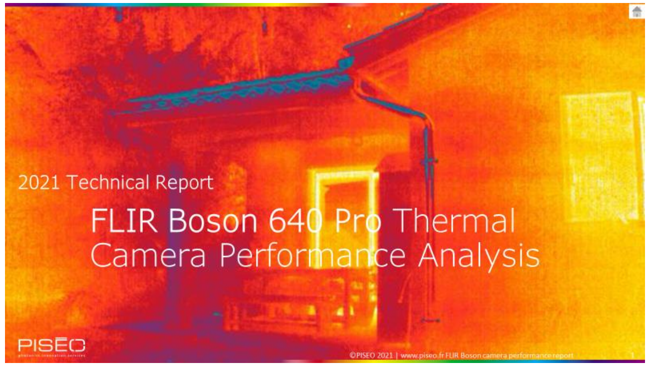
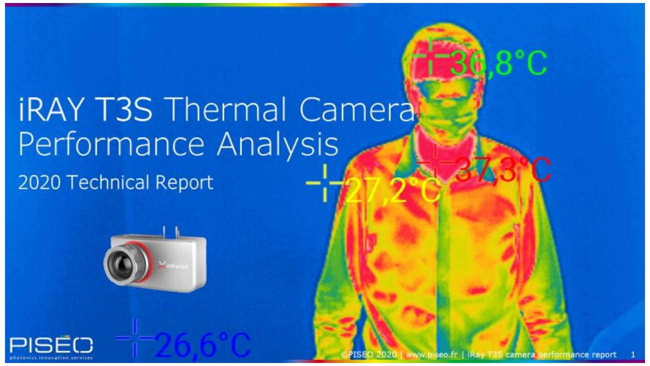
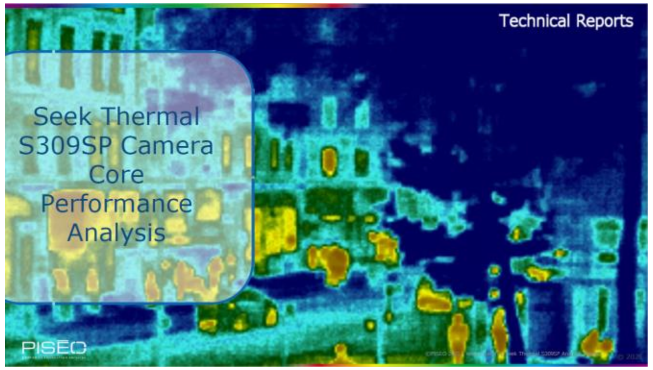
[FLIR Boson Thermal Camera Performance Analysis]



[iRAY T3S Thermal Camera Performance Analysis]



[Seek Thermal S309SP Thermal Camera Performance Analysis]



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