Call for Presentations

THERMOSENSE XLIV

Vendor Presentation and Reception XVIII

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Gaylord Palms Resort & Convention Center

Orlando, Florida, USA
Monday 4 April 2022

SPIE. DEFENSE+ COMMERCIAL SENSING

Guidelines - Scope / General and Specific Topics

Vendor Presentation and Reception is now in its 18th (eighteen) year and has become very popular. This venue provides an early opportunity for exhibitors to highlight their latest technology and products to the Thermosense and infrared community, prior to the opening of the DCS-2022 exhibits. This also enables the technical conference attendees to better prioritize their activities when visiting the exhibits.

It is a casual meeting with ample time for questions and answers. Looking for state-of-the-art in future generation of infrared imagers and thermometry (all bands) radiometric and non-radiometric as well multispectral and hyperspectral imaging technologies. Both in updates and new developments - innovation: hardware, software, new applications, accessories, artificial intelligence applied to the field, big data sources, assembly of data sets, calibration, quality control (e.g. lenses, detectors, coolers, cameras etc.), systems integration, standards, training , infrared industry market trends.

Your company must be an exhibitor at Defense + Commercial Sensing Expo 2022 to be part of this event. Any DCS-2022 exhibitor that offers products or services related to infrared sensors or images; photonics can participate. The content of the presentations has no restrictions and may have scope: technical - research - academic - commercial. Are accepted additional topics that are not within the presenters manufacturing and development framework. For guidance, please check on pages N°3 through N°13 list of topics: products, services and applications which may be of interest to the audience. (*)

Slots are limited and available on a first come first-served basis. The list of participating vendors and the content of their presentations will show up in the final program of the SPIE DCS-2022 symposium.

Primarily audience background

Researchers in innovative infrared systems, Innovative infrared applications engineers & professionals, Advanced optics engineers, Photonics & imaging researchers, Photonics engineering, infrared systems engineers, Calibration & Test engineers, Academics, Physicists, General Exhibition-Only Visitors, Exhibitor Representatives (SPIE DCS-2022)

Basic rules:

- Be Exhibitors at SPIE : SPIE Defense + Commercial Sensing at Gaylord Palms Resort & Convention Center - 2022
- All exhibitors are eligible to present.
- First-come first-served basis --------------- Slots are limited ⇐

Guidelines:

- Abstract - Manuscript: **not required**
- Presentation on site: flexible. Power Point (PP) other
- Presentation contents of the chosen topic : technical - manufacturing - commercial - practical - research : **no restrictions** (*)
- Presentations in this session do not have prior review. As always, presentations within ethical and professional standards are expected.
- Vendors may bring and display equipment-instruments during the presentation (hardware -other)
- Length of presentation around = 12'- 16' - TBD
- When and where the session takes place: Orlando, FL – USA - starting Monday, April 4 - 2022 from 12 pm - (noon). It is not ruled out at this time that eventually some presentations could be scheduled for Monday morning same room - TBD

Information required to apply :

- Legal / commercial name of the company - booth number-not being defined yet: TBD - (SPIE DCS - Orlando 2022)
- Title of the presentation
- Name of the presenter, affiliation, position in the company
- Contact information of the presenter (e-mail)
- Brief introduction of presentation's content (one line)

  Example of basic information required : ####

Company name: ### **(Booth N° #### or TBD)**
Title presentation: ###
Presenter name / surname: ############# **Position in the company**: #################
Presenter e-mail: ##

If you are interested in participating or have any questions, please contact:

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Link to

Thermosense : XLIV Academics   +   Vendors XVIII + SPIE DCS 2022

https://spie.org/SI22/conferencedetails/thermosense

Find below in alphabetical order: a list of **general and specific topics related to the infrared Industry - Technology,** which may be of interest to the audience: infrared technology hardware, accessories, lenses/crystals, software, signal processing, artificial intelligence, compliances, standards, training, patents etc. The content-presentation topics have no restrictions. Below list is only a guide for **vendors** and **does not cover all industry or audience interest topics** --It is just a **guideline** Rev. 2021 (new)

⇨ **Active Infrared Thermography IRNDT (TNDT):** set-up --- Infrared camera (cooled /uncooled) -computer system (processing), digital imaging acquisition, Thermal Excitation: optically stimulate (surface optical heating- non-uniform heating concern) - Thermography - heating control unit-- Heating lamps = xenon flash-light - long pulses or short pulses / narrow or wide angles (light pulse wide spectrum = VIS +NIR) and halogen lamp / floodlights VIS +NIR (e.g. tungsten / quartz halogen) ---Inspection techniques e.g., Pulse thermography (transient), Pulse phase thermography (Discrete Fourier Transform -DFT), Step heating, Lock-in thermography (modulated), Frequency modulated thermography.-- Another thermal excitation techniques: lock-in vibro-thermography, burst vibro-thermography, laser stimulated, mechanical excitation, electromagnetic inductive-eddy current, (e.g., crack depth certainty with inductive thermography), ultrasonic excitation (e.g., characterization of vertical cracks) convective fan-forced, heaters, coolers devices, infrared emitters, warming blankets (contact excitation), others. Software, lamps cables & tripods. Potential convection effect during the test. Another modular architecture. Planning prior to an evaluation of materials with IRNDT-- Statistical evaluation of test data for different techniques, thickness-geometry and type or group of material (Big data and the potential use of AI). Advantages, disadvantages, limitations and practicality of the different IRDNT method for specifics materials/ applications - Signal Processing Techniques for IRNDT (See below alphabetical order: Signal Processing Techniques) (26) (32) (48)

⇨ **Advanced Driver Assistance Systems (ADAS)**: Thermal (LWIR) or/and SWIR cameras integrated to a self-driving systems with other sensors as LiDAR, radar and visible cameras ,sonar, GPS. Driving and parking functions. Driver Vision Enhancement (DVE / SWIR) KIT (+ SWIR illuminator) Clear visibility in darkest conditions (20)

⇨ **Artificial Intelligence (AI):** Platforms: Applications for thermal imaging, visible and SWIR. Artificial Intelligence based in infrared sensors IoT (+ other technologies sensors). Big data (structured, semi-structured and unstructured) Hadoop ,data mining, data analytics Vision algorithms. Machine learning-(ML), Deep Learning (DL), Artificial Neural Networks (ANN) applied to the field. Sensors with embedded processors (IoT). Applications in which infrared industry has more potential and those where may be difficulties or be unprofitable for the application. Risk and cybersecurity-privacy. Potential applications in the infrared industry in its own manufacturing process (e.g. camera calibration, detectors manufacturing, others). Datasets for different applications. Programing - coding (e.g. Python), algorithms implementation. Global ISO 8000 standard for data quality and company master data. (34) (36)

⇨ **Benchtop Testing with IR Cameras kits:** capabilities of benchtop systems versus handheld and portable thermal devices. e.g., Testing repairing printed circuit boards. Standard and custom electronics (6) (40)

⇨ **Binoculars - Monocular:** SWIR pocket scope -Thermal : multi-function thermal binocular, weapon sights, helmet, head, mounted, handheld. Periscopes. Other long range thermal weapon sights. SWaP (HOT detector), thermal binoculars and cameras specific integrated in drones. Binoculars & Monocular for personal vision system: rifle monocular, adventure, camping, surrounding environment amusement others. Multifunction portable optronic devices (42)

⇨ **Blackbodies - Calibration:** Measurement and calibration standards - Collimators-Cavity blackbodies - Extended area blackbodies - Differential blackbodies - Low temperature blackbodies - Control software for blackbodies-Target projectors -Portable calibration devices - Vacuum temperature blackbody - Primary Standards for Temperature Calibration (Calibrations and Standards) -Temperature (radiation) metrology. Uncertainty (systematic and random)- Target projectors for sensor test and characterization capability from ~0.30 um to ~14 um. Low-cost Blackbodies. Uncooled Focal Plane Array. Test Systems (characterization and calibration of several FPA simultaneously) Specific blackbody systems for COVID-19 (other diseases) as a thermal reference area in the field of view of thermal infrared camera systems that seek to detect EBT. ISO 17025 - accredited calibration, a complete uncertainty analysis. Uncertainty calculation requires in ISO 17025. ISO/IEC 17025:2017 Requirements: List of Documents outline and summary Estimation of measurement uncertainty. Traceability of measurements. MODTRAN (moderate resolution atmospheric transmission) Calibration of active SWIR sensors (emitter and receiver- proximity sensors. Transform voltage values into centimeters) e.g. precise measurement of distance from obstacles to the robot. Sensor calibration.

⇨ **Blower Doors:** For airtightness of buildings test and locate air leakage sites in the building envelope. Used together with thermal imaging for distinguish between air leaks and gaps in the insulation and another type of failure or defects in house and (building depressurization).Test blower using an infiltrometer. Building gradually decreases so air to enter through unsealed openings, poorly sealed openings, or cracks, that can be seen by an infrared camera. ISO 9972. Blower door single and multiple fan. (45)

⇨ **Cameras Accessories:** Power supply, cables, lenses, carrying case, wall mount, tripods, microscope stands. Advances in batteries technologies- Fast battery charger. Headset, lens cap, grip belt, Infrared cameras power consumption, AC220V / DC12V power adapter/ charge, others

⇨ **Cameras General Guidelines VisNIR - VisSWIR- SWIR - MWIR - LWIR:** Portable – Handheld thermal Infrared cameras - non-Portables. Fixed-mount cameras. Cameras opto-mechanical designs. IR cameras for passive & active applications –Cameras non-radiometric and radiometrically-calibrated (accuracy ±°C/F %). Standard temperature range (radiometric camera: e.g. 20°C to 650°C (-4°F to 1202°F)- Radiometric data streaming- Camera storage & operation temperature (°C or °F). Camera Functions-features settings: auto Functions, spot meter, isotherms, emissivity corrections, adjustments for atmospheric (MWIR) & ambient temperature, gray and color scales of images , effects reflection, focus, digital zoom temperature range, spectral response range (µm- microns) Image format (e.g. jpg), Field of View (FOV - H° X V°), IFOV (instantaneous field of view / milliradians = (mRad). Frame Rate (e.g. full window), time lapse (sequence of frames at intervals) Cool down (photon detectors) - time to image, isotherms, humidity, ambient temperature, background

temperature span and level correction. Pixel drift. Electronic noise. Level sensor - regulations. Smart thermal infrared portables cameras to simplify tasks (+ avoid human errors). Synchronization and triggering features. Infrared cameras connected and integrated with other test and measurement instruments. (e.g. multimeter). Cameras focus motorized or manually. Cameras with exchanging lenses. High speed infrared imaging: Resolution fps at full frame and fps in sub window mode. Cameras Sizes and Weight and Power (SWaP). (33) IDCA = Integrated cool Detector- Dewar - cooler - assembly. Day-night functionality. Cameras Built-in GPS for inspection identification location coordinates. Camera data storage level. Camera hardware flexibility. Cameras (cool detectors) for gases detection: with infrared cameras.(e.g. methane, SF6, ammonia, CO, CO2 etc.). Snapshot exposure capability. Uncooled cameras shutter-less technology. Integration Time (e.g. .x ns to ~ full frame). Filter holder (warm filter). Camera f/# (f-number). Infrared cameras for space programs (Remote Sensing) qualified-customize systems. Pilotage Distributed Aperture Sensor (PDAS) Spherical infrared imagery. Total Power Consumption. VisNIR camera & target illuminator. Camera Testing Equipment. Includes VIS-SWIR Cameras. Fusion of visible and infrared images. SWIR cameras range 0.9 to 2.7 µm spectrum. Scene dynamic range. High resolution, low noise, cooled, digital SWIR cameras (very low dark current). Cameras focus motorized or manually. Cameras with exchanging lenses. Cameras remotely controlled. Cameras Built-in GPS for inspection identification location coordinates. Camera hardware flexibility. See also Linear Photodiode Arrays InGaAs (SWIR) and Line scan Cameras SWIR - SWIR pocket scope. Highspeed visible cameras (VIS) (high resolution and high-speed CMOS camera) Filter holder. Cameras operating humidity. Strong VIS and NIR response and ultrawide bandwidth from 350nm through to 1100nm - Cooling SWIR camera. Scientific SWIR cameras. Smart cameras (21)

⇨ **Cameras Cores :** Original Equipment Manufacturer (OEM) - Based uncooled thermal imaging module. Components– Shortwave SWIR / Midwave MWIR / Longwave LWIR –(cool -uncooled) – Automotive cores - Low-power cores. Cores enable for SWaP. Advanced computer vision capabilities. Embedded processors in infrared sensors (e.g. for AI to identify findings).Thermal imaging engines (video engine). IR-Modules

⇨ **Cameras & Detectors Characterization - Additional Features** : Focal Plane Arrays- Acronym: FPA or staring-plane array. Architectures monolithic or hybrid. Detector package vacuum tight (metallic - ceramic). Resolution-detector format (pixels - H° X V°) mm² = Number of pixels - Sensor diagonal -Pixel pitch (µm / center-to-center) - Bad /dead pixels. Bad-pixel replacement (BPR). Pixel well capacity. Readout Noise. -Cell Fill factor. <u>Figure of merit / performance</u>: R (Responsivity) - D-Star (D* = detectivity) watts - Cutoff Wavelength (λc) µm - Spectral responsivity (Rλ) volts/watt - Spectral resolution λ / Δλ - NEP (noise equivalent power) watts - Quantum efficiency infrared detectors (%) & Peak Quantum Efficiency (QE)- Thermal Sensitivity / NETD (Noise equivalent difference temperature- SNR = 1) e.g. : <50 mK typical – Element Temperature (Td) °C. Thermal time constant (T =63.2%) . MTF (Modulation transfer function) - MRTD (Minimum Resolvable Temperature Difference) - SRF (Spectral response function), SiTF (signal transfer function) – SNR (Signal-to-Noise ratio -dB) – Signal noise improvement -Dynamic range (e.g. 14-bit) - Repeatability - Non-Uniformity corrections (NUC) - Radiance uncertainty reduction - Response time - Linearity through the full dynamic range -Nonlinearity - Frame Rate/full window (Refresh rate Hz) - Snapshot - Integration time (µs) or Selectable integration time (µs to ms). Mean time between failures (MTBF). Sensor cooling (e.g. closed-cycle rotary) Spatial uniformity, Dark current, Crosstalk probability . Specific Read-Out Integrated Circuit (ROIC). Video engine for cooled & uncooled thermal imaging systems. Image Sizes (detector format) = Image size VGA (Video Graphics Array -640 x 512 pixels) - XGA Extended Graphics Array (XGA) (1,024 x 768 pixels)-SXGA Super Extended Graphics Array (HD resolutions - 1,280 x 1,024 pixels) -- Digital or analog output signals (output formats). Detectors across the waveband, for space instrumentation qualified (cameras systems) observing radiation looking at the earth. As well space qualified visible, hyperspectral and multispectral systems. New materials (HOT detectors) Systems qualification & performance tests. Quality Assurance

⇨ **Cameras: Environmental Housing-Enclosures:** Environmental Rating: Waterproof/Dustproof (IP/NEMA) Environmental protection Shock / Vibration standards ISO - IEC. Rear connectors appropriate for environmental standards requirements. IP69K (ISO 20653), to test the devices that require this regular and intensive cleaning (high pressure and /or temperature washes). This standard has been replaced by ISO 20653 Mount interface. Operating Temperature Range- Storage Temperature Range- Homologation and validation of IR systems for extreme environmental conditions: ice, spray water, salt fog, sand/dust, extremely high and low temperatures, altitude, extremely low or high humidity (potentially equipped with cooling and heating, systems). Anti-thunder. Seal waterproof, Anti-acid rain. Ultra-Rugged Infrared Cameras designed to survive and be to deploy in the extremely harshest conditions. (IP68 Rated - Waterproof to 2 Atmospheres) Image Stabilization (vibration reduction) . Environmental stress testing . Intrinsically safe (camera): Series Explosive Atmosphere Standards ATEX and IECEx certifications. Humidity and submersion Camera systems in magnetic environment or used for measurement in ionizing atmosphere Vandal resistant proof e.g., IK10 camera. Thermal imaging surveillance cameras with housing alternative: Dome vs Bullet vs Turret (integrated with VIS cameras and AI) . Explosion proof bullet camera e.g., for petrochemical industry

⇨ **Cameras: Interface Options & Connectors:** (rear panel/other) / Command and Controls (hardware general): Digital output option. USB 2.0 - USB3 Vision interface -Gigabit Ethernet socket interface (GigE Vision) – GenICam - Ethernet cable- Power supply - HD Video = HD-SDI video output, HDMI (High-Definition Multimedia Interface), SPI video interface, API application programming interface. Composite Video: NTSC: 60Hz / PAL: 50Hz, S-Video, SVGA USB, RS-232 /Analog RS-170 and CCIR / IEEE-488 GPIB, Camera Link (CLHS) HS standard and full fiber / CoaXPress -CXP (single and dual link) ,Wi-Fi , Wi-Fi HaLow TCP/IP, Others – Interface / Commands Cables lengths and transmission of data. Factors that can determine the maximum cable length in each case (e.g., speeds). Audio connections if applicable- SD memory card. Infrared camera connection to complementary instruments via Bluetooth, Bluetooth Low Energy (BLE), Zigbee (communication protocols- IEEE 802.15.4), RFID (Radio Frequency Identification). A lens mount is an interface – mechanical and often also electrical – between an infrared camera body and a lens itself (22) **Drones Interface Options :** communications ports options CAN - I2C – UART - RS232, RS422, RS485 -PWM -- Protocol MAVLINK interconnection with the ground + other drones to perform. RPAS (Remotely Piloted Aircraft System). External GPS connection, External trigger. Remote Control: e.g. Via Wi-Fi (when in range)

⇨ **Cameras Hyperspectral Imagery (HSI) ⇔ Imaging spectrometer:** HSI different types of sensor (e.g. snapshot tiled sensor). Pushbroom vs Snapshot imagers. Hyperspectral: not output a 2D image. A hyperspectral data cube or image cube (three dimensional). Systems over one hundred contiguous spectral bands (much narrower bands than multispectral e.g. 10 nm-20 nm). Contiguous narrow spectral bands . Spectral Range (µM available in MWIR and LWIR). Identification and characterization of materials VNIR (400-1000nm) --NIR (900-1700nm)-- Extended VNIR (550-1700nm) SWIR (900-2500nm) Spatial Resolution. (IFOV-pitch), field of view, spectral resolution: wavenumber (cm ⁻¹), temporal resolution - Wavelength intervals. Calibration. Thermal Resolution (NETD). (MWIR -LWIR) Exposure Time. Remote Control, Trigger(39)

⇨ **Cameras Multispectral Imagery (MSI):** Multispectral spectral bands VIS + NIR. Multispectral spectral bands VIS + NIR + SWIR. Multispectral spectral bands SWIR + MWIR. Multispectral spectral bands VIS + LWIR. Multispectral cameras concentrate on several preselected wavebands (e.g., 3 to 10 bands). Multispectral cameras: number of spectral bands and spectral bandwidth of each band FWHM = full width at half maximum Spectral bands of varying or no varying bandwidths. Multispectral cameras mounted under agricultural drones. Use the filters to separated wavelengths. Number of spectral bands and spectral bandwidth. Detectors depending on the camera spectral bands: CCD- CMOS - Indium arsenide (InAs), gallium arsenide (GaAs), or indium gallium arsenide (InGaAs), can be used to collect light up to 2600nm. NIR through the MWIR, a mercury cadmium tellurium (MCT or HgCdTe) sensor, indium antimonide (InSb) focal plane array, indium gallium arsenide (InGaAs) focal plane array (39)

⇨ **Cameras on Surveillance Platforms :** (short-long range) Pan / Tilt unit (angular accuracy – both continuous degree range). Outdoor marine in conjunction with SWIR and VIS cameras and other sensors: laser rangefinder, (measuring resolution- range- eye-safe) - laser designator, zoom imager. Camera controller, via Ethernet and change different settings. Long-range surveillance applications. Systems e.g. border protection, critical infrastructure, vessel traffic monitoring, airport /harbor perimeter surveillance. Long -range military multi-sensor camera systems from visible (VIS) to thermal imaging

⇨ **Coatings:** For lenses, mirrors and filters. High Hardness, Scratch and Corrosion resistant coatings. Abrasion and corrosion resistance. Anti-reflective coatings (enhance transmittance improve optical efficiency). Coating tested for abrasion and chemical durability. DLC and other high-durability coatings . Plastic-coated optics. Coating methods and types = different technologies for coating. Coating test type and metrology Multiple thin-film coatings accurate: photolithography process. Thickness uniformity of coatings. Multispectral coatings. Edge filter coatings. Hydrophobic coatings, Oleophobic coatings, Extreme ultraviolet coating (EUV). Hot mirrors or hot reflection (reflect the infrared radiation) and cold mirrors (transmit the infrared radiation). Metallic mirror coating (Gold/ Au—Silver /Ag – Aluminum /Al). VIS (surface conditions of objects): Instrument surface reflectance analyzer: haze, image clarity, BRDF, gloss (surfaces diffuses or like mirror) (39) (53)

⇨ **Compliances:** ➤ **ITAR Certified (compliant):** International Traffic in Arms Regulations (ITAR). Trade restricts and control. Education and trained in ITAR regulations. ITAR compliant testing services for evaluating. Export Classification. ITAR free (23) ➤ **Cybersecurity Compliance:** e.g. Controlled Information or internal controls required by the buyer (authority, industry, other) to the vendor/contractors to protect the confidentiality, integrity and availability of data in the supply chain of the product or service . For example, certification like: Cybersecurity Maturity Model Certification (CMMC) and Cybersecurity Framework (NIST) Protection infrared industry or service networks from cyber threats, malicious business personnel and human error (24) ➤ **CE compliant** European health, safety, and environmental protection standards. ➤ **Pharma FDA-EMA**… compliance NIR spectroscopy. Other compliance frameworks

⇨ **Cryogenics - Cryocoolers Stirling Engine Technology:** Different cooling methods. For a variety of different areas : space programs qualified, defense and commercial. Linear and rotary Stirling coolers. Cryogenic & Vacuum Systems - Miniature Cryocoolers - Parameters in cryocoolers like noise, vibration, efficiency. Fast cooldown systems - New developments and advances in cooler for infrared systems. Dewar's. Cold shield infrared cool detectors. Integrated Detector, Integrated Dewar Cooler Assemblies = Assembly or integrated detector cooler assembly (IDCA). Integral rotary - Split rotary –Split linear - A linear Stirling cooler for extreme ambient temperatures -- Miniature Joule Thomson Cryogenic-- SWaP cryocoolers. SWaP extend longer cooler lifetimes. High reliability rotary cooler – Commonly used refrigerants (operating gases). Control drive electronics for coolers. Thermoelectric Cooling Solutions =TE cooled detector (thermoelectric –Peltier-- cooling modules). Integrated Dewar cooler assemblies

⇨ **Detectors ⇔ Sensors type dominant materials** (basically imaging)**:** ➤ **VIS -NIR- SWIR:** Materials: InAs - InGaAs Wavelength range of ~ 0.9 to ~2.8 μm. SWIR Dual-mode sensor =Detectors Si (Silicon) - ~ 300 nm to 1200 nm (visible -near infrared). SWIR quantum dot sensors = Colloidal Quantum Dot (CQD) -- CMOS-InGaAs SWIR detectors –SWIR Comparison variation of quantum efficiency (QE) with wavelength (λ) between InGaAs and QCD detectors. VIS CCDs charge-coupled device Visible Imaging Sensor 380 to 780nm (RGB Color Camera) Electron Multiplying CCD (EMCCD) sensors- Back-illuminated sCMOS **– MWIR-LWIR Quantum - cooled systems:** ➤ **Photon detectors** – PtSi - InSb -HgCdTe (MCT) - QWIP (Quantum Well) -- JT Detectors. Trade-off between detector quality and lens quality. From linear to large staring formats. Detectors epitaxial layer. **HOT Detectors:** (High Operating Temperature) ➤ **New generation of IR sensors**: nBn sensors barrier detector technologies -- SLS (strained layer superlattice) -T2SL (Type II Super Lattice) - Sensors temporary work ~130 Kelvin (K) to ~175 Kelvin (K). **SWaP:** (acronym) **-** IR device or system,(Cameras Sizes and Weight and Power. (Payload-friendly) Future developments and reduce overall SWaP - See more detail in cameras. **SWaP- C**: (acronym) -- IR device or system Size, Weight, Power and Cost.--**Microbolometers - Uncooled systems / Broad Band LWIR (+MWIR) :** ➤ **Thermal detectors:** Vanadium Oxide (VOx) and Amorphous Silicon (α-Si) -- e.g. 30 Hz / 60 Hz (9 Hz alternative option) –Detectors uncooled- Ferroelectric: Barium Strontium Titanate (BaSrTi = BST) (33) (38) (47)

⇨ **Drones - Mini Drones :** Multi-missions airborne drone. For various types of payloads (cameras-VIS - SWIR – MWIR - other) and applications. e.g. dual payload drone gimbal -- Single Rotor Helicopter - Multi Rotor Drones: Tricopter (3 rotors), Quadcopter (4 rotors), Hexacopter (6 rotors) and Octocopter (8 rotors). Hybrid VTOL Fixed-Wing, see Unmanned Aerial Vehicle (UAV) as well. Drones for specific indoor & confined spaces inspections. Drones moving in droves. Integration of multiple sensors. Drone countermeasures. Drones mounted with VIS cameras, infrared cameras (SWIR/LWIR), lidar and hyperspectral imaging systems (3) (4) (9)

⇨ **EBT Elevated Body Temperature /systems screening - EST Elevated Skin Temperature / systems screening (EST)- COVID-19:** Thermometry (canthus values) –Thermal imaging technology for places or areas with high human traffic for both public and private activities - Thermography - Setup and different methods – (early indication when used properly of one potential symptoms of a viral infection). ISO/TR 13154 Medical electrical equipment — Deployment, implementation and operational guidelines for identifying febrile humans using a screening thermography. Uncertainty in normal body temperature (T) (age, time of the day-circadian, thyroid hormones etc.). Broader environmental conditions (air flow, natural and forced, humidity, temperature). Blackbody reference for stability (14)

⇨ **Fibers Optics & Fiber Optics Sensors** transmit VIS-NIR-SWIR   Plastic Optical Fiber (POF) - Glass optical fiber - Multimode Fiber /Single mode Fiber transmission from 650 nm - 1625 nm (we mainly infrared region): General Fiber-optic sensor. Advantages - disadvantages (e.g. immune from the effects of electromagnetic interference -EMI, low power) -Cost. Types. Intrinsic sensors and extrinsic sensors. Wavebands in VIS-NIR SWIR - laser or any super luminescent source. (e.g. 850nm, 1300nm 1550 nm) .Fiber Bragg Grating (FBG). Applications e.g. measure strain , temperature, liquid level others etc... Transmission compares with wireless (cyber secure etc.) Fiber-optic sensor for non-contact radiation measurement (47)

⇨ **Filters Cameras:** Filter types - vision applications   . Neutral density filter - Cold filters and Warm filters. Spectral filters(place in a filter holder): neutral density filter or spectral filters itself. Wide band thermal imaging laser protection filter (WPF). Dynamic Sunlight Filter for cameras and for surfaces (VIS + NIR) Filters that selectively transmit (not absorb) or reject-reflect an unwanted wavelengths. Filter transmission band applications. Angle of Incidence (AOI) Bandpass filters. Notch filter. Dichroic filters. Multi-bandpass filters Spectral slope filter installed, the camera / filter system new calibration. Fog filter. Custom filters. Measuring optical filter spectra using a spectrophotometer spectral slope. Filter installed, the camera/filter system new calibration. Infrared blocking filter (e.g. blocking NIR wavelengths). Custom filters. Dual band filters. Coating stress. Coating failures. Precision Infrared Narrow Bandpass (34) (35)

⇨ **Firefighters Infrared Cameras:** Handheld and aerial specific infrared cameras. NFPA and other associations compliant. Firefighter personal thermal imaging. Wireless charging systems. Accessories (49)

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⇨ **Gyro Stabilized Platforms & Gimbals:** Camera Mount /with multiple sensors (e.g. infrared , visible ,SWIR) Continuous 360° Pan. laser rangefinder laser illuminator. Applications: Defense and Homeland Security ,Broadcasting (sports etc.) Cinemas. Used in wide range of industries. Gyrostabilized line of sights. Gyro stabilized platforms observation system as well for antennas, weapons. Gimbal Camera Payload Applications Gimbals in boat UAVs, Drone, aircraft, others

⇨ **High Speed & Definition Cameras:** (VIS - NIR - SWIR - MWIR - LWIR) resolution, frame rate, and sensitivity. Transferring the data off the camera. Camera Synchronization. External camera Triggering Control. Start and stop acquisition options (camera -software). Frames per second at full resolution. Sub-windowed for faster rates. High speed object tracking (47)

⇨ **Imaging Spectro Radiometer:** Micro-Spectrometers--Hyper Spectral Imaging system--Instruments for measurement: Directional reflectance / Hemispherical emissivity -Spectral / Total directional emissivity / Bidirectional reflectance (BRDF) spectral/total--Directional hemispherical transmittance

⇨ **Infrared Lenses-optics:** Infrared lens choices /Technology. Material for lenses manufacturing: e.g. Germanium, Zinc selenide, Silicon, Calcium fluoride, Glasses etc. Auto & Manual focus, Infrared Mechanical Zoom Lenses (Continuous zoom- Motorized Continuous Zoom) , Focus preserves through the zoom. Lenses with continuous metric zoom. Zoom lenses integration with existing systems. Dual Field of View lenses (DFOV-discrete zoom lenses)-Fixed zoom – Lenses f-number (F#): -Effective Focal Length (EFL) mm - Vignetting – Narcissus effect— Preventing optical aberration in design and manufacturing lenses. Lens new materials. Grinding and polishing. Aspheric and spherical lenses- Microscopes lenses- Lens design for specific sensor. Anti-reflection coating options. Broad band anti-reflective. Mechanical performance. Potential lens failures and their solution: spatters, contamination, scratched lens edges, loss of coating. Boresight. Ruggedized infrared lenses instead of standard imaging lenses. Shock and vibration stability. Ingress protection from heavy fog, water ingress, dust. Customized Infrared Optics Lenses. Adaptive optics. Lenses for environment of temperature fluctuations (thermal change) and the resulting system defocus: Athermalization solutions (compensation). Etendue in an infrared optical system. Multispectral optical systems. Maritime imaging lenses. VIS-SWIR Lenses. SWIR fixed focal length lenses. Motorized SWIR lens. Recognition & Identification (DRI) ranges. Optical parts for missile guidance detection and recognition. Infrared camera: choice of lens depending on the detector available. Lenses custom requirements domes or flats. Different types of Lenses mount.(e.g. C-mount, CS-Mount, others) Lenses accessories. Reduced SWaP Zoom lens designed. Infrared lightweight Zoom Lenses: Close-up Lenses / Microscopes. (22) (39) (40)

⇨ **Infrared Lens - Optics Testing Equipment:** for the measurement of optical image quality from the ultraviolet to the far infrared. Infrared Optics. Dynamic Interferometry. Measure optics surface roughness. Optics Metrology. Optical parameters (Astigmatism, Distortion, Strehl ratio, others) Coatings Metrology.(see coatings) Optics Assemblies Metrology. High end MTF testing in the infrared optics. Optics Testing Standards. Choice the proper lens for a specific FPA. Protective glass for protection of the lens from dust and scratching. Infrared lenses absolute transmission test. Infrared optics test benches. Testing of camera modules. Diamond-turning machines capabilities for different qualities . Measurement systems for virtual and augmented reality optics. Image quality testing lenses in a wide spectral range. Athermal designs: Testing image quality for different temperature ranges. Infrared lenses alignment and centration test. 3D Optical Surface Profilers. Coherence Scanning Interferometric (CSI) profiler - Bulk material or thick film Index / Birefringence measurement. 3D surface profiling: visualization and metrology - platform for surface characterization. Quality Assurance Systems

⇨ **Infrared Mirrors:** Materials shapes: flat, conics, aspheres – Reflectors-Metallic and dielectric reflection layers. Mirrors coatings. Hot mirrors / Cold mirrors. Highly reflective coatings (39)

⇨ **Infrared Sensors – Detectors** (others) **:** Pyroelectric detector range around 2 to 14 µm. Gas, Industrial & Medicine Thermometry - Photo Conductive Materials Detectors: PbSe (lead selenide uncooled - cooled) spectral range from 1µm to 4.7µm -- PbS (lead sulfide) a standard sensitivity in the 2µm to 3.8µm. SWIR semiconductor detector. Nano thermometry - Non-Contact Infrared Temperature Measurement - Line scanners – Pyrometers. Accuracy. PIR (passive infrared sensor- motion detector), or PID sensors applications. PIR sensors to perform better and to have a higher signal to noise ratio. Robots active IR sensor AIR (emitter and receiver- proximity sensors) pair can accurately note whether an object is, and active configurations Calibration of active infrared sensors (voltage values into centimeters) nano sensors (nano thermometry). Flexible - stretchable temperature sensors. Infrared sensors with embedded processors (see IoT -IIoT) BioMEMS Nanomaterials & electronics technology applied to sensors. Semiconductor materials for IR sensors. Thermal and VIS Cameras for Space: restricted applications. Qualified and of suitable design for use in space. (34) (38) (46) (47)

⇨ **Infrared Signature:** Infrared signature, tracking, modeling target, Thermal imaging , atmospheric effects . Infrared sighting and tracking. Track Systems. Hardware and software. Thermal Signature Reduction (48)

⇨ **Infrared Windows Medium Voltage Switchgear & Electrical systems:** semitransparent materials (crystals), Properties: optics, mechanical, thermal, chemical. Infrared spectral transmission (%)-waveband Δλ , geometry, dimensions, coated-uncoated, UV sensitivity, Protective covers, Certifications. Arc flash test, Vibration test. Ingress protection testing (NEMA Rating or IP Equivalent), other tests. Mounting and fixing on the asset . environmental indoor -outdoor. Other infrared windows customized shapes, finishes, different sizes, thicknesses. (Semitransparent materials) Infrared Windows - Enclosure Mount Thermal Imaging / Sensors - FPA – Remote Thermal electrical Panel Check **:** several alternatives. Thermal Monitoring Infrared Sensors e.g. miniature infrared thermal sensor – FOV - IP Network - Smart wireless -Network IP camera- LAN-- Format - Intelligent vigilance others. Embedded e.g. with deep learning algorithms others Thermal module detect deviation inside panel. Data (AI) e.g. centralize in SCADA (Supervisory control and data acquisition) - M2M --Autonomous or supervised actions to be carried out in different scenarios - IIOT (Industrial Internet of Things) - LTE 5G: (Long Term Evolution - Fifth generation of wireless technologies) (40)

⇨ **Internet of Things (IoT - IIoT) + Sensors :** IoT platforms. Infrared industry sensors involve and integrate with another sensor. Infrared devices, sensor ,OEM. Network connections LTE-5G / ISP Wi Fi - IPv6. Heartbeat light sensor (infrared) . Nano sensors (*) (nano thermometry). IoT sensors: body temperature, liquid level sensor (infrared),proximity and presence (PIR) infrared, heartbeat light sensor (infrared), infrared encoder/decoder. Other wearable: head, neck, arms, torso, and feet and many more . Breathable and stretchable temperature sensors inspired by Skin epidermal electronics Sensors and actuators in embedded systems. Smart objects and sensors. Smart dust. MEMS (Micro Electromechanical Systems) as technology for its possible massive implementation in IoT. Manufacturing high-performance sensors and actuators for IoT (intelligent dust)– (*) NEMS nano-electromechanical system integrate electrical and mechanical functions at the nanoscale. Miniaturized electrical and mechanical apparatuses such as actuators, beams, sensors, pumps, resonators, /motors IR sensors embedded processor (6) (34) (9)

⇨ **LiDAR:** (Light Detection and Ranging or Laser Imaging Detection and Ranging) self-driving car and other vehicles (mining trucks and agricultural machinery) programs together with thermal sensor, sonar, visible and radar . LiDAR by type of laser or by scan type.

⇨ **Linear Photodiode Arrays InGaAs (SWIR):** wavelength ranges (~ 1.45 μm and 2.6 μm) selectable bandwidth, pixel pitch, applications

⇨ **Linescan SWIR Cameras:** InGaAs different types. Rates, dynamic range, wavelength response, quantum efficiency, e.g. applications in machine vision moving objects: food or agricultural product sorting

⇨ **Microscopes with Thermal Imaging Capabilities:** Thermal-Hyperspectral. Lenses. Size of the smallest objectives that can be solved quantitatively by a given infrared microscope. Infrared microscopes applications. Micro-electromechanical system (MEMS). Radiance (temperature) distribution over the surface of a compact and fragile devices and many more (40)

⇨ **Miniature Infrared Cameras:** for weight & space constrained environments: LWIR cameras (microbolometers) - Miniature SWIR cameras (InGaAs) - Miniature Payloads. Thermal weapon sight (42)

⇨ **Mobile Smart Phones:** integrated with thermal imaging devices

⇨ **Modular and Automated Systems (IRNDT)-Thermography-camera-kit:** for various active Infrared non-destructive testing inspection in other to detect voids, cracks, corrosion, delamination, water inclusions, others mostly in composites material and characterization of thereof. Modular and automated systems to detect flaws in electronics and semiconductors (26) (32)

⇨ **Night Vision:** (image intensifier) monocular, binocular, rifle mounted, goggles, long range devices (42)

⇨ **Pan & Tilts Platforms :** speed, acceleration, command rates, controller, payload platform, vehicle-mounted applications, max payload weight, Tilt Range up and down up 180 °, minimum pan (panning) speed, Minimum tilt speed. Minimum velocity / Maximum velocity (Az & El) Pan Range (e.g. swivel to the left and right/complete 360° circle to smaller areas) Heavy-duty Pan /Tilts + zoom (PTZ). Anti-salt fog (25) (37)

⇨ **Patents in Infrared Industry- Photonics** Innovation and Entrepreneurship. Copyrights and intellectual property. Patents granted. Patent last ? Examples of Patents in Photonics. European Patent Office (EPO) - The United States Patent and Trademark Office (USPTO) - Japan Patent Office (JPO) -Korean Intellectual Property Office (KIPO) others

⇨ **Platforms for Remote Sensing:** miniaturized remote sensing instruments Space. HAPS (high altitude platform station) Aircraft positioned above 20 km altitude, Air, Ground, Sea For surveillance of maritime zones, land borders or critical assets or for example forest fire monitoring

⇨ **Robots Integrated with Infrared Devices :** autonomous, teleoperated, humanoid, different speed & size, adapt to workspace. Robots with a temperature screening solution automated, contactless and touchless solution for screening and detecting EBT individuals and other health risk factors associated with the pandemic COVID-19 and other disease. Land-based remotely controlled vehicle equipped with infrared cameras - others for hazardous areas. Surveillance robots with visible and thermal cameras to patrol industrial-manufacturing sites, warehouses and different assets (33)

⇨ **Semitransparent Materials:** Infrared windows, lenses, prisms, and filters. Infrared windows coatings. Precision thin film coatings Abrasion and rain erosion protective and related hard coatings. Finished Infrared Optics Mechanical toughening/ strengthening for semitransparent materials (low absorption in the infrared spectrum). MWIR: 3-5 μm transmitting materials -LWIR: 8-12 μm transmitting materials.(Al2O3 Sapphire, BaF2 Barium Fluoride, CaF2 Calcium Fluoride, Ge Germanium, Infrared Plastics HDPE / TPX, (MgF2) Magnesium Fluoride , (Si) Silicon, (ZnS) -Irtran-2-Zinc Sulfide – (ZnSe), Zinc Selenide others), Chalcogenide Glasses in general , UV-VS-NIR transmitting materials (AMTIR GeAsSe – Glass, BK7 Schott Glass etc…). Optical wedges. Crystal breeding. Prisms. Birefringence crystal example. Beam splitter optical component (split light in two: by intensity or wavelength) Infrared dual-band (MWIR–LWIR) - Gradient Index (IR-GRIN). Transparent in the Visible e.g.,BK7 optical glass, quartz glass, UV-grade fused silica, Pyrex others (34) (35) (39) (40)

⇨ **Signal Processing Techniques for IRNDT (TNDT)** applied data processing algorithm over the raw infrared image to improve the SNR. Signal processing techniques such as thermal contrast, differential absolute contrast (DAC), principal component thermography (PCT), thermographic signal reconstruction (TSR), and pulsed phase thermography (PPT). Techniques are required to enhance contrast, to improve the spatial resolution and to increase the signal-to-noise ratio of the infrared signal (32)

⇨ **Software - Image Acquisition - Image processing:** Infrared signature software analysis / Real time analysis software (thermal imagery changes over time) -- Software Development Kit (SDK) for custom-tailored applications- Thermal modeling & FEA software- Infrared image documentation software –Energy Audit software. Signal processing software. Barcode & Labels Printing data base IR Software. Interpretation of thermal images: 3D. Image Contrast Enhancement. False color scales apparent radiation ranges. Thermography basic reports available for iOS and android. R&D software compatible program with MATLAB + SIMULINK., C++, Python others. Thermal image processing: Image acquisition (timing/trigger), Timestamping IRIG-B output (Inter-Range Instrumentation Group) recording, display and data analysis. Gain control, Contrast-Limited Adaptive Histogram Equalization (CLAHE), denoising image process (temporal /spatial), Sharpening and Local Area Processing (LAP). Image Stabilization (vibration reduction), ROI (Region of Interest) , Infrared-Visible image fusion. (blending images)- Frame grabbers- Intelligent Electronic Devices (IEDs) To make an accurate decision and find the origin of cyberattacks (networks, IIoT). Thermal infrared software for multiple platforms and languages . ROI / AOI = region of interest / area of interest

⇨ **Standards and Certification Related to Infrared Industry:** Companies certification ISO 9100/D Quality Management System – Requirements for Aviation, Space and Defense Organizations --- ISO 14001 Environmental Management System (EMS) -- ISO 18251-1:2017 Non-destructive testing — infrared thermography (Technical Committee: ISO/TC 135/SC 8 Thermographic testing). ISO 9712 is Non-destructive testing, –Qualification and Certification of NDT personnel-- ASNT SNT-TC-1A. -- ISO 10880:2017 Non-destructive testing — Infrared thermographic testing — General principles National Aerospace Standard: NSA 410 (published by AIA) minimum requirements certification of nondestructive testing (NDT). - Compliant MIL Standards example: Military standards MIL-PRF-13830B (optical components-surfaces quality)- MIL-C-48497 (coatings) - MIL-C-48496 - MIL-STD 810E e.g. = Low Pressure (Altitude), High Temperature, Low Temperature, Shock Solar Radiation (Sunshine), Rain, Humidity, Fungus, Salt Fog, Sand and Dust, Explosive Atmosphere , Leakage and Immersion, Acceleration, Vibration, Acoustic Noise, Shock, Gunfire, Temperature- Humidity- Vibration- Altitude, Icing / Freezing Rain, Functional shock, Vibro-Acoustic-Temperature/ MIL-STD 810F / MIL-STD-810G (environmental engineering considerations and laboratory testing). Military Specification: MIL-C-675C /Coating of glass optical elements (anti-reflection)—Others: Certified ITAR Professional® (CIP). Cybersecurity compliance certification (CCC). ISO 55000:2014 Asset management physical assets such as: plants and industrial facilities, buildings, machinery, vehicles and other. Condition monitoring techniques establishment, implementation, maintenance and improvement of an asset (e.g. thermography, Vibration analysis, temperature monitoring = thermometry, lubricant analysis, tribology, passive ultrasound others.) ISO 9972:2006 Thermal performance of buildings Determination of air permeability of buildings - Fan pressurization method. NFPA 1801 Standard on Thermal Imagers for the Fire Service (23) (24) (41) (45)

⇨ **Terahertz (THz):** Materials and devices. Sensors and Terahertz imaging cameras. Electronics / Detectors (Far Infrared FIR - 15 µm - 1000 µm overlaps with terahertz radiation)

⇨ **Thermometers Non-Contact - Pyrometers:** (infrared devices fixed – handheld thermometry): Medicine (e.g. Covid-19), Firefighters, Environmental + Applications in harsh conditions (agriculture/agronomy) Monitoring industrial equipment (condition monitoring). Industrial process. Precision ad high temperature pyrometers. Two color pyrometer (e.g. kiln burning zone) Thermometers to measure temperature of cooler objects (e.g. cooling chain testing in the food industry). Plastic, glass, metals manufacture, processing and testing, Semiconductors and electronics and many other applications. Various industries require precise temperature measurements under different emissivity, reflected apparent temperature and atmospheric parameters. Photodetector Type Si (38) (46)

⇨ **Training- Education :** Recommended training for general and specific infrared camera and applications, different IRNDT techniques (physics, methodology, hardware, software). Pre-purchase and post-purchase sales support. Certification training (e.g. ASNT LEVEL III examination) formal training, experience, examinations, vision examinations. Infrared applications: training for flying drone indoors and outdoors environments (41)

⇨ **Uncooled or Cooled Thermal Imaging ?:** which one should I choose for my application? The right choice for different purposes and applications: industrial, research & development, academics, security defense, aerospace, others. Quantum (Cooled) vs. Thermal Detector (Uncooled)

⇨ **Unmanned Aircraft Systems (UAS) - Unmanned Aerial Vehicle (UAV) - Fixed-Wing + Drones:** UAV payloads**.** Stabilized EO gimbal based visible & thermal infrared. System Integrator. Specifications Software-Controlled flight aerial monitoring- Airborne Imaging Systems. Data integration Thermal, GPS location, Visible, others. Drones for indoor inspection and inaccessible or confined space. Flyability of use. Unmanned aerial vehicles (UAV) to acquire image and video material. e.g. thermal and multispectral imaging for day and night real-time vigilance at operational level. UAS (Unmanned Aircraft Systems) = includes UAV + personal and systems on the ground + all systems onboard. Autonomy (3) (4) (9)

⇨ **Wireless Infrared Systems:** Space qualify IR-Outdoor scanners - Infrared remote sensing systems others

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(*) **Additionally** below table shows in alphabetical a list **industry-specific applications and topics** (+some hardware). Those vendors that produce **goods or services linked** from what is listed or presenter with experience in any of them, are welcome to share it with the audience. This table it is **only a guide for vendors** and does not cover all topics of interest to the industry / audience Rev. 2021 (new)

⇨ **Active Near-Infrared Illumination:** (NIR) – observation - vision devices using active near-infrared illumination (21)
⇨ **Active Infrared Thermography:** Examples of active thermography (without a direct contact: device and inspected area) with different techniques-test development, thermal excitation sources and on different type of materials, shapes and thicknesses. Characterize and find defects in different materials / thicknesses without damaging them and wide inspection. Applications in materials like composite materials: CFRP /GFRP /CARALL /GLARE (fiber metal laminate) sandwich structures other metals, ceramics, fiber reinforced polymers. Surface, sub-surface defects. Advanced nondestructive testing procedure. Active Infrared Thermography characterization of smart materials (intelligent or responsive materials , to e.g., electrical, mechanical, chemical signals other). Embedded smart materials-SMs. Detection accuracy of defects with the different techniques of active infrared thermography. Research and Academia (26) (32) (48)
⇨ **Additive Manufacturing:** (3D printing) Product process monitoring-heat monitoring for emergent additive manufacturing -Defects characterization for different materials –process (metals-polymers) with thermal systems (32)
⇨ **Aerial and Portable:** home auditing infrared systems. Aerial (drones or helicopter) thermography commercial roof and building envelops infrared inspections. Thermal 3D mapping. Many other applications (2) (31)
⇨ **Agriculture Classification-Inspection:** with multispectral, hyperspectral imaging - SWIR-NIR VIS. Basically, with Drones. e.g. early plague detection /improved crop health /drought /vineyard management. Agri-food (2) (3)
⇨ **Aircraft Landing Assistance Systems**: using thermal and SWIR sensors. Enhanced Vision System (EVS) for aircraft landing in limited visibility environments. Normally pilots for landing use ILS stands for = Instrument Landing System (high or low and the other telling them if they are left or right of the runway)

⇨ **Art Inspections:** with thermal and SWIR cameras. Infrared reflectography. (51) Historic buildings investigation SWIR as Non-Destructive Analysis: of underdrawings in art objects (17)

⇨ **Artificial Intelligence (AI):** Collection of data (big data) and algorithms analysis/selection for different potential and profitable applications in the infrared industry arena. Examples of real applications (33) (34)(36)

⇨ **Asset Monitoring:** with IR Thermal systems (e.g. city heating system operators). Thermal inspection in electrical assets. Condition monitoring. Find deterioration in assets (private and public) and plant sites (2) (24)

⇨ **Athletes Footwear**: thermal imaging cameras - systems analysis for improving comfort - foot cushioning - health - improve aerobic fitness - injury prevention

⇨ **Augmented Perception in Infrared:** Augmented vision and nonvisual imaging in short wave infrared, thermal infrared and hyperspectral bands. Augmented-reality-based systems

⇨ **Automotive Manufacturing Inspections:** e.g. Brake disk control, robot spot weld continuous inspection (IRNDT). Heated seats / window heating test. Automotive Airbag Inspection (1)

⇨ **Automotive Night Vision Camera:** systems (SWIR + Thermal) (cars & trucks & buses & rail) – Passive Driver Assistance Systems. Drive help with Infrared cameras in foggy conditions

⇨ **Autonomous Cars** (driverless): Cars-Trucks - Agriculture Equipment - Mining Machines - Autonomous Vehicle Construction (haul trucks) - Autonomous Electric Minibus - Watercraft - Robot Patrol Autonomous Vehicle (driverless): use of thermal camera as a complement to other sensors: visible light cameras, LiDAR (light detection and ranging), radars, (radio detection and ranging), ultrasound. Advanced driver assistance systems (ADAS) IR sensors applications . Driving and parking functions (20)

⇨ **Autonomous Robots:** navigation (Indoor & outdoor navigation) using infrared devices + others. Robots with visual and thermal cameras security solution for commercial, industrial facilities, surveillance

⇨ **Ballistic and Explosion:** characterization, weapon launches, large caliber arms - high-speed events study and analyzed with infrared systems energy measurement - characterization of ballistic . Bullets in flight: Real-time image bullet tracking. Track and characterize events from an explosion

⇨ **Battery Technology:** development of batteries with the aid of thermal imaging cameras. Battery thermal modeling and characterization

⇨ **Biometric Security:** future of thermal imaging technology. Thermal infrared face recognition. Biometric identification or verification technique and complement with visible cameras.Face recognition with thermal camera in low light

⇨ **Biology - Microbiology :** e.g. thermography detects the latent heat of freezing for a cluster of biological cells. … many others application in biology

⇨ **Bug Disinfection:** (termites or hornet nests) Detecting using of thermal infrared technology (13)

⇨ **Buried Mines:** infrared thermography to the detection and characterization of buried landmines (wider, detect as well other buried objects) multispectral imaging for presence of e.g. underground missiles etc.

⇨ **Characterization of Materials (Thermal IRNDT/TNDT):** Analysis and investigation in materials thermal properties. heterogeneous, homogeneous, isotropic, anisotropic materials flat and non-flat plates (e.g. curved surface: cylindrical and spherical shapes) Thermal diffusivity, Thermal conductivity, Thermal effusivity, specific heat. Identification of thermophysical properties with IRNDT (TNDT) e.g., Composites . Sandwich structures. Carbon Fiber Reinforced Plastic CFRP, Glass Fiber Reinforced Plastic GFRP - Carbon reinforced aluminum laminate CARALL, Glass laminate aluminum reinforced epoxy GLARE, Polymers, metals, Fiber metal laminate (FML), porous ceramics etc. Applications e.g. aerospace, architecture, athletics automotive, energy, infrastructure, military, shipbuilding, repairs ships, wind turbine blades, others. Photothermal Techniques: Photothermal in the characterization of composite materials, Illuminating the surface of the sample with a laser light beam modulated or pulsed (26) (32)

⇨ **Chemical Imaging (CI):** hyperspectral and multispectral imaging applications. Basically, hyperspectral imaging: spectral, spatial and temporal chemical mapping

⇨ **Commissioning / Recommissioning**: Thermal imaging in power plants several applications (+extended life), building envelopes, HVAC systems testing .Other's infrastructure ventures (2)

⇨ **Counterfeit Banknotes:** detect with SWIR sensors. Counterfeit currency detection. Complement of UV counterfeit detection

⇨ **Counting People:** with thermal 24 Hs. (microbolometer) and visible cameras: shopping malls, stadiums, retail stores, clubs, hotels, business metrics, neighborhoods, parks …others

⇨ **COVID-19 Pandemic** (coronavirus pandemic): and other diseases (SARS, Bird Flu, Ebola, Dengue) : doctors / authorities support detecting elevated body temperature (EBT) that provide prevention (indoor and outdoor installations) : airports- cruise ships ,train stations- bus stations- harbors -hospitals -schools -factories -markets–government facilities, check points, immigration, shopping malls, stadiums, retail stores , others key locations. CO2 emissions of the exhaled air people breathing is absorb at specific waveband in MWIR. -- MWIR infrared camera + filter at $\lambda = 4.3$ µm (microns), to detect / visualize CO2.- Carbon dioxide (CO2) in the airway of a patient during his respiratory cycle is carried out by capnography (CO2). Evaluate the effectiveness of a mouth-nose mask how far from the mask the exhaled CO2 + possible coronavirus reaches) as well comparing the CO2 flux without a mask and the effectiveness of several masks with each other. CO2 flow analysis for mask design. COVID-19 diagnostic test using spectroscopy (VIS-NIR) or other optical technology for virus detection (14)

⇨ **Cultural Heritage:** conservation / preservation. SWIR , thermal, multispectral, and hyperspectral imaging (27) (17)

⇨ **Customize Infrared Systems:** Specific and define applications. EO / infrared systems customized for a wide range of applications: short range, mid-range, long range distances and environments

⇨ **Concealed surveillance IP:** Internet Protocol :IP - Thermal Infrared Camera Security mini hidden Camera—Wi Fi IP cameras -Remote monitoring from any location (30)

⇨ **Dams- Bridge Deck - Road pavement / Monitoring:** Example cracks in the concrete (e.g. Dams) Thermal Imaging involves. Health and damage detection of large structures bridges ,dams and tall buildings. Roads, pavements /bridges patching area, hidden defects or damages in the road or bridge pavement structure foreign bodies, road marking, road joint . Analysis and survey of the state of the pavement (41)

⇨ **Defect Characterization IRNDT: discontinuity - types of flaw /damage:** General draft list of possible defects (material, geometry or techniques) : e.g., lack of adhesive, cavities, core crushing, corrosion damage, cracks, porosity, voids, delamination, debonding, fiber and ply misalignment, fiber distribution (e.g. GFRP – GPRS), fiber orientation, fiber concentration, fiber undulation/wrinkling, honeycomb cell wall damage, impact damage, material inclusions / slag, material inhomogeneities, matrix / fiber cracking, micro-cracks, near surface inhomogeneities, paint delamination, cracks under cyclic loading (fatigue), subsurface defects, thickness variation, non-uniform fiber/resin volume ratio, vertical cracks, water ingress (e.g. honeycomb), evaluation of coating thickness, other flaw not necessarily rejectable, other irregularities/flaw - Potential materials: e.g., artificial polymers, ceramics, others composites materials, highly conductive / diffusive materials, honeycombs, metals, natural polymers, non-magnetic metals, very thin materials, plaster, wood, others Defects dimension/ location: e.g., defect size - dimension, defect depth, surface defect, defect lateral size, shape of a defect, defect orientation, others.(26) (32) (48)

⇨ **Detect and Track Drones flying: Approaching or moving Away:** with VIS and thermal cameras (+ zoom) Target Recognition (TR) Drone/Not Drone identification (4)

⇨ **Detection – Recognition - Identification Ranges - (DRI):** comparison of various infrared systems and for different targets and distances. Johnson criteria (29)

⇨ **Domotics:** massive IR sensor use in everyday life basically with IoT (household appliances, kitchen, backyards, gardens, perimeter fences) - Thermal Imaging and Thermometry

⇨ **Drainage-Recycling Networks:** systems for monitor heat. (Thermal imaging cameras) : district heating and drinking water networks (reservoirs, treatment, and distribution); drainage networks (sewerage or sanitation -and sewage stations); recycling networks (waste collection, landfills, incinerators). Surveys on ecology. (31)

⇨ **Drones + Applications:** Infrared (IR) Inspection service in high voltage power lines, distribution and substation systems, monitor buildings and infrastructure, gas leaky, land, crops, wildlife, geothermal environments, cattle count , thermal imaging to locate bird nests on farming, land security, search & rescue (SAR)-support firefighters, emergency service, public safety drones. The fields of application of drones with thermal imaging (+ others imaging systems) can be as wide as our imagination. Drones image recognition (VIS +Thermal) pay load to map trash (e.g. plastics in oceans). Surveying, and mapping. (Drone Detection & Verification From military uses to the most commercial and civil ones, it is common for the drone to carry some type of payload on board to perform some specific function for which it is intended. Drones equipped with thermal cameras: for carrying out radiometric temperature measurements = Radiometric drone thermal camera (e.g.**COVID19** ,others) (3) (4) (9)

⇨ **Earth Observation Satellites (EO)- Satellite Imagery:** Systems for different altitudes & purposes: thermal, VIS, SWIR, multispectral and hyperspectral imaging cameras /sensors systems-- thermal imaging sensors on satellite platforms applications -Space (deeper space) Military a non -military applications e.g. environmental monitoring, meteorology, cartography. Thermal imaging cameras-systems on satellite platforms applications to observe the earth-EO (land -oceans, ice, atmosphere, volcanoes -weather)- Space (deeper space). Others imaging sensors (28) (46) (52)

⇨ **Elderly People:** Living alone remote care (control) : fever control (radiometric device), privacy, detect movements with thermal cameras keeping privacy. Specific microbolometer radiometric connected IoT

⇨ **Electrical Inspections:** Buildings, houses, industries, refineries, power plants, substations, universities, hotels, transmission lines, stadiums, labs, harbors, airports ..everywhere) Faulty Connections**,** degradation in electric cables /overloaded circuits-Thermography Systems (portable + fixed 24/7). Infrared electrical inspections identify hot spots caused by bad connections and worn out (24)

⇨ **Energy Audit**: Facilities, buildings: Infrared cameras and software. Thermal infrared as a tool for energy performance certificates (EPCs)

⇨ **Energy Efficiency Air Leakage:** refrigeration-weatherization using Thermal and SWIR cameras

⇨ **Energy Infrastructure Systems Monitor** Thermal imaging cameras involves in dams, Eolic - windmill farms, geothermal, nuclear power plants, high voltage systems, medium voltage systems, low voltage systems, transformation, distribution, public lighting, oil pipelines, oil fields, gas pipelines others critical energy Infrastructure concrete (2) (24)

⇨ **Environmental and Pollution:** impact assessments with hyperspectral and multispectral imaging. Contaminant detection with SWIR devices. Fire at waste. Environmental monitoring: e.g., health of the plants, regions treated with chemicals, state of the soil, something harmful is present (12) (27) (39) (49)

⇨ **Explosives, Drugs / Narcotics:** detection with hyperspectral imaging. Applications with thermal imaging (+ SWIR) (27)

⇨ **Finite Element Analysis:** in heat transfer

⇨ **Fire Fighting:** Thermal and shortwave Infrared (SWIR+ LWIR) Cameras. Fire Fighters handheld thermal cameras tool for use inside fire scene. Firefighting in hazardous areas. Systems for early fire protection (1) (49)

⇨ **Flare smokestack monitoring:** monitoring with thermal camera the flame / pilot flame that flare up the gasses e.g. Petrochemical process plants (avoid having gases enter the atmosphere)

⇨ **Floods-Natural Disasters:** assistance and support with thermal cameras Disaster response drones equipped with cameras. glacier monitoring /outburst flood risk mitigation (9)

⇨ **Fluid Systems Pipeline -Blockages - Detection of leakage / spills** (water - oil and natural gas – sewage- district heating): buried (underground) and surfaces pipes (above ground pipelines). Thermography systems (portable + payload in a drone). Inspections -broken and leaking pipes.- Detect change in humidity on the temperature of the ground due to evaporation.

⇨ **Food Quality and Safety:** Spectrometry - Hyperspectral Imaging: food processing - Types of food processing - various degrees of food processing – fresh food - e.g. steps of processing fermenting, concentrating, microwaving, packaging, others (14) (27)

⇨ **Forensic Sciences:** (latent evidence) applications with Imaging Systems (thermal / hyperspectral) + Ultraviolet Forensics Imaging. Thermal systems used for evidence identification in forensic sciences (7)

⇨ **Forest Fire Fighting:** Infrared integrated systems complemented with the change in physical & chemical parameters of the area. Flame and smoke detection algorithms. Wildfire fighting (1) (10) (49)

⇨ **Forestry Management:** with thermal and hyperspectral imaging e.g. classification of forest tree species

⇨ **Fourier Analysis Experience:** Fourier transform (FT -numerical algorithm) mathematical transform applied in infrared industry research, application in general e.g. Thermography –IRNDT (TNDT), Fourier Transform Infrared Spectroscopy…others. Fourier Transform is used in a wide range of applications image processing and many others (26) (32)

⇨ **Fraudulent Products:** detection with thermal imaging systems or completed with another waveband

⇨ **Fusion Imaging:** With any of the following alternatives UV - VIS - NIR - SWIR - MWIR - LWIR. Integrated Vision Systems

⇨ **Future Thermography Applications :** Future of the infrared industry applications ? Users of different specialties constantly request new applications both for thermal infrared camera, and all other bands and image fusion. Integration, reworking and emergence of new applications due Artificial Intelligence (ML + DL). Big data challenges

⇨ **Gas Leaks**: Infrared systems (fixed + handheld) for detect & Identification and quantify gas leakage (+ emissions). Gas compounds Acids, Hydrocarbons, Organics, SF6, Flare's control pilot (flame) others.

⇨ **Geology – Seismological – Seismic Hazard:** Multispectral and hyperspectral surveying, and mapping with passive optical imaging systems = Spectral geology multispectral systems to identify spectrally rock types and surface materials, lithological and mineral mapping, hydrocarbon exploration, geochemical analysis. Damage of buildings after an earthquake for emergency rescue, loss assessment and rebuilding (11)

⇨ **Glassmaking:** Infrared system for imaging & temperature measurement. e.g. SWIR glass bottle defect inspection. SWIR cameras image through glass, for example to inspect interior and exterior walls of the bottle + temperature uniformity . Thermometry in glass making industry e.g. at higher temperatures glass surfaces better measured with 5.0 μm or 7.9 μm. In those spectral bands glass emissivity is ≥0.95.

⇨ **Handheld Scanners NIR:** (pocket instrument) Near-infrared spectroscopy for almost instant fit: nutritional information & fingerprint & quality from food we daily eat (14)

⇨ **HAZMAT:** (Hazardous Materials Response Team) Events using visible, thermal, multispectral and hyperspectral imaging to protect life, property, assets minimizing environmental impact. ATEX environment (3)

⇨ **Hidden Security Infrared Cameras:** for various applications (e.g., tactical & covert surveillance) see Concealed (30)

⇨ **Honeycombs Composites Specific Inspections:** e.g. Thermography-camera-kit for detection trapped water (e.g. aircraft rudder) other e.g. military, rotor crafts, automotive, rail, ships, wind turbines, machine platforms.-- Debonding between the skin and the honeycomb -Face sheet delamination, Honeycomb cell wall damage -Absence of adhesive-Core crushing. Honeycomb cell wall damage (26) (32)

⇨ **Hydraulic Systems:** general reliability & security tests with infrared cameras (thermal) e.g. oil leakage, temperature of different part of the system: valves, tank, filters, oil

⇨ **High-Shock Environments:** Qualification of multiple sensor surveillance systems: high frequency, high amplitude shocks--high temperatures, high radiation, high shock, and chemically corrosive environments

⇨ **Hyperspectral Imagery (HSI) :** Hyperspectral measures / adjacent / contiguous spectral bands, (e.g. NIR /SWIR/MWIR) Hyperspectral imagery for identification and characterization of materials as well detect exclusive objects in the scene. For plastic sorted - recycling (PP - PE - PVC - PET, and PS); for agriculture and precision forestry and other environmental applications (study of the environment in general) ; For monitoring: landfill biogas emission (methane), natural & liquefied gas leaks greenhouse gases; for movement of slope-forming materials including rock, soil, artificial fill, or a combination; for study hydrology (e.g. Flooding), coastal monitor; for mineralogy, quarries, and aggregates. See: Geology – seismological – seismic hazard. HIS analysis for skin tumor detection (11) 16) (27) (39).

⇨ **Hypersonic Aerodynamic:** improve with thermal imaging cameras /systems - Hypersonic (> Mach 5), wind tunnel with a thermal imaging camera. Test systems and their capability to withstand airflows

⇨ **Industry 4.0 - Fourth Industrial Revolution:** Condition monitoring involved and integrated in Industry 4.0 IIoT (industrial Internet of things) in horizontal and vertical business integration with infrared and other .systems. Massive interconnection of systems and digital devices (process -instruments, sales, suppliers, customers) IIoT challenges for infrared industry. Higher Connection Speed LTE-5G (Long-Term Evolution - Fifth Generation) – high-speed & low latency (8) (24)

⇨ **Infrared Homing:** (Infrared tracking - passive weapon guidance system) -- to track a target and follow it. - heat-seekers - false heat source

⇨ **Infrared Reflectography:** SWIR cameras with illumination floodlights rich in NIR+SWIR e.g., Investigation of works of art. See through paint layers preparatory sketches retouching, signatures and dates others (51)

⇨ **Infrared Systems - Cybersecurity IIoT:** (industrial internet of things) Threats. Secure, reliable communications sophisticated identity and access management of infrared and other sensors.

⇨ **Integrated Imaging Systems:** applications in: Harbors, Rail station, Airports, Subways, Bridge's protection, Prison Security, Police & Law Enforcement other

⇨ **Insurance Claims Modeling:** (legal requirement) Insurance companies that help customers to minimize loss and rates with using thermal imaging

⇨ **Internet of Things (IoT):** Smart cities and smart buildings/ houses (domotics - home automation), automotive many others thermal Imaging and thermometry applications. Potential platforms, areas and applications in which the measurement of infrared radiation (temperature) can involve autonomous detectors which can interact with each other and other sensors from other disciplines-applications. MEMS low-cost, high-performance very small sensors and actuators. (Intelligent dust) Actuators: electrical, hydraulic, pneumatic, mechanical others (36) (8)

⇨ **Intrusion Detection :** smart video surveillance solutions (Thermal +VIS)

⇨ **Ladle check:** refractory infrared monitoring System. Real time monitoring and give a warning of excessive shell temperature (42)

⇨ **Laser Rangefinder:** and laser pointers for different applications with an infrared camera (industrial ,surveillance, military...)

⇨ **Linear Photodiode Arrays InGaAs (SWIR):** applications in: NIR spectroscopy, hyperspectral airborne imaging, machine vision, radiometric measurement (thermometry if ~ > 150°)

⇨ **Maintenance Proactive - Condition Monitoring:** Thermography Systems for monitoring Specific Industrial Plants/Utilities. AI with communications real time alerts via SMS, SCADA, or email (24)

⇨ **Maritime Orientation:** and search for diurnal- nighttime heat signatures in cloudy, smoke and hazy environments with infrared thermal and SWIR systems. Maritime Multi-Sensor Stabilized System applications (11)

⇨ **Mechanical Industrial Equipment:**-condition monitoring: warm motor (e.g. internal winding problems) / bearing failures, shafts, others. Mechanical assets / assemblies (24)

⇨ **Medicine -Thermology - Healthcare:** in general. Disease screening and evaluation with infrared thermographic imaging systems. -lumbar, shoulder, face, hand, tissue abnormalities, muscular pain, neuralgia, breast , knee, thyroid ,peripheral vascular, musculoskeletal. Thermoregulatory -Metabolic Thermal test protocols used in medicine. Medical Legal issues. (e.g. USA -FDA : thermography should not be used in place of mammography to detect, diagnose, or screen for breast cancer). Limitations of Thermal Imaging Systems in Medicine. When are thermal imaging systems considered medical devices? (14)

⇨ **Micro-Electronics-Electronics: Design &Test:** thermal imaging cameras / Microscopy systems for minuscule -tiny targets (e.g. semiconductor) Printed circuit board (PCB). Electronic circuit boards design and test**. MOSFET** (Metal–oxide semiconductor field-effect transistor) design challenges, with thermal imaging, Microelectronics & micromachining: Thermal properties and heat dissipation for improving overall design. Photonic integrated circuit (PIC) .Thermal infrared NDT (6) (40) (46)

⇨ **Micro-Thermography** (**Microscope):** Temperature measurement in the micrometer range. Instrument use e.g. Micro-Radiometric thermal imaging microscope. Application areas: Tiny medical devices (6) (40)

⇨ **Mineralogy & Geology Mapping:** Multispectral imaging cameras and hyperspectral imaging for mineralogy prospecting and airborne mapping (11)

⇨ **Military & Surveillance:** mid and long-range integrated systems. Law Enforcement Special Forces. Long-range, all-weather integrated multi-sensor security surveillance systems. Gyro stabilized platforms: (+ gimbals) For long range applications are the speed, spectral response, spatial resolution. How to choose or select infrared camera system for certain applications :wavelength of the camera, speed, spectral filters, optics, transmission of the atmosphere to operate, operational site weather, estimated temperature & distance from the target .. budget for the project etc.

⇨ **Multi Sensor Surveillance systems:** For **D**etection, **R**ecognition and **I**dentification (DRI) From detection device into a deterrent (mitigation) applications: for borders, coastal. Anti -Blooming mechanism (29)

⇨ **Multispectral Imagery (MSI):** Multispectral as opposed to hyperspectral imagery measures separate / spaced spectral bands. Land surface and landscape distiguish characteristics-features. Agriculture optimizing the use of pesticides, fertilizer and irrigation. Study of the environment (Biosphere: about deforestation, carbon recycling, lithosphere degradation, erratic weather patterns. MSI for detecting or tracking military targets. Multispectral machine vision applications combination of visible and non-visible wavelengths to check and evaluate the extrinsic features / characteristic (color, surface damage, shape etc.) and intrinsic features / characteristic (dry matter content, mature fruit, moisture, sugar, fat etc.) (39)

⇨ **NDT techniques applied individually together with IRNDT non-destructive infrared tests passive or active:** IRNDT + = ultrasound, X-ray, terahertz, visual, magnetic particles, liquid penetrants ,other

⇨ **Neonatal Thermoregulation :** monitoring with thermal sensor /camera (newborn = sick or low birth). Incubator virtual monitoring + IoT (14)

⇨ **Ordnance Testing:** Munition testing. Muzzle flash analyses . Multi-spectral Signature Analysis. Other

⇨ **Opaque Materials (plastics) – Detect Liquid Levels**: see with SWIR InGaAs technology's liquid levels in plastic bottles, silicon , level in opaque containers in pharmaceutical industry, other (27)

⇨ **Passive Infrared Sensors (PIR):** Automatic lighting applications (ON -OFF), security system, PIR Presence motion detection alarms, measure temperature of a remote object ,others. Application in IoT (34)

⇨ **Passive Infrared Thermography** : It is a non-invasive, non-destructive and non-contact technique result and, unlike **Active Infrared Thermography**, it does not require thermal excitation. In passive thermography the target of interest is naturally at a higher or lower temperature than the background. Widely applied in different fields and most of the applications listed above and below in this Call for Presentations are passive. Only the imagination limits the applications of passive thermography. Do you have any thermogram (active or passive) to share with the audience? Thermogram a digital image displays or two-dimensional printed copy of the apparent temperature representative of infrared radiation from scene. Heat map of the scene in black and white or pseudo-color

⇨ **Pest Control:** house remediation with thermal cameras. Find mammals such as mice as well wasps' nest, hornets, rodents. termites, bedbugs. Search for clues related to a thermal camera (13)

⇨ **Petrochemical Monitoring:** Continuous monitoring of refractory reactors. Automated, continuous thermal imaging to identify thermal abnormalities within petrochemical pipelines. Monitoring Critical Assets inside plant

⇨ **Photolithographic:** (optical lithography): used for patterning of optical coatings (53)

⇨ **Photonic Integrated Circuit** (**PIC**) Gallium Arsenide, Silica on silicon Silicon on insulator, Lithium Niobate, Indium phosphide (InP), other- Optoelectronic components. Thermal management: photonic integrated circuits and integrated electronic circuits using IR thermography e.g. applications data communications, general sensing, biomedical, in the defense. The use of protons as data carriers. Hybrid & Monolithic Photonic Integration (6) (40) (46)

- **Photothermal infrared spectroscopy (micro)** e.g. bacterial, contamination microplastics
- **Pollution Monitoring:** detection and emission characterization of smokestacks / chimney with thermal, multispectral, and hyperspectral imaging cameras (12) (27) (39) (49)
- **Precision Agriculture & Farming systems:** Land usage: management and crop health applications with hyperspectral imaging. Thermal: estimating soil water status and crop water stress, (3) (27)
- **Printed Circuit Boards (PCB):** Infrared Thermography systems in Electronics and microelectronics. MEMS micro-electromechanical system (6) (40) (46)
- **Process Control in Industries:** (machine vision -includes SWIR) & Industrial workers safety. Thermal systems for Industrial automation, optimize products and improving product quality. SWIR InGaAs line scan for different application of machine vision (27) (33)
- **PTZ (Pan-Tilt-Zoom) - load -range - speed:** multi sensor surveillance systems - Pan/Tilt unit with different performance levels for infrared systems indoor and outdoor (10) (25) (37)
- **Recycling Plastic:** with SWIR cameras InGaAs (Indium gallium arsenide) Sorting plastics in the waste stream. Hyperspectral Imagery (HSI) (16)
- **Refractories & Missing Insulations:** thermal infrared inspections = Thermography systems (portable + fixed 24/7) for boilers, furnaces, etc.
- **Robot Assistant/Auxiliary:** with thermal devices (touchless and contactless) solution for screening and detecting EBT (COVID-19), firefighting support robot, others
- **Robots Systems:** applications in industry, defense, security, firefighting, quality control with thermal and visible imaging cameras. Robots for nuclear remediation / decommissioning
- **Rotary Kiln Scanner:** fixed thermography systems   (e.g., cement kiln)
- **Science - Research & Development** (**R&D):** Fast motion events (Ultra-High-Speed infrared cameras - High-speed Visible cameras), stress analysis, Industrial lab test bench , Thermal imaging for R&D / -- NDT Systems for Laboratory Materials science**,** thermoplastic material, lack of adhesion spraying layer, Welding and materials testing. Characterization of new materials (e.g. composites, polymers) process monitoring. Research for automation and quality control, development of new products. Artificial Intelligence (Machine Learning - Deep learning) developments for different infrared applications (1) (26) (32) (34) (36)
- **Scoring-Aim a Target:** With infrared thermal-- detection target-- recognition target - using spatial temporal information (moving target detection)
- **Search and Rescue (SAR):** Terrestrial, water based, aeronautical with integrated visual and thermal cameras + drones – helicopters. Involved search and track (9)
- **Security in Commercial Applications:** Trends perimeter and indoors protection in several applications: power plants, industries, parks, landscapes, indoors/outdoors: home security, banks, zoos, museums, malls others (VIS+ IR cameras /PTZ) (10) (25) (33)
- **Seepage and Moisture, Mold:** Detection in many places: government /commercial building , facilities, house city infrastructure etc. using Thermal infrared cameras (and digital water leak detector). Moisture patterns, mold claims and rot- moisture accumulation, condensation, infiltration, and leakage in wall systems and windows (13) (31)
- **Signatures Analysis:** (infrared) -- Rocket, missiles – flares signatures in infrared bands. Flare countermeasure-Thermal signatures in a field test environment. Source of radiance. Infrared signature of naval ships. Target infrared signature acquisition and analysis. Infrared Signature Suppression (IRSS)
- **Slag Detection:** Infrared monitoring system. Detect slag in molten steel (42)
- **Smart Infrared Sensors**: IoT e.g. with embedded processor. Overheat or Δt scene input that make sensor to takes some predefined action --- MEMS micro-electromechanical system (36)
- **Solar photovoltaic cells SWIR (InGaAs) inspection:** test for uniformity (cell efficiency- electroluminescence -photoluminescence inspection)
- **Solar Photovoltaic Cells:** Thermal test: modules, panels, and arrays: lightning, storms, overheating defective cells, panel hotspots damaged module, sun reflection defective bypass diode, damage dirt caused by bird, open-circuited string, Impurities, humidity, pollution, other. The use of drones for photovoltaic solar panel inspection. Different techniques and strategist. New Flexible solar cells infrared applications analysis
- **Solar Thermal Power Stations:** (solar farm) Continuous thermal infrared monitoring 24/7 (overheating, focusing others) Types =parabolic trough - solar power tower concentrated - Fresnel reflector commissioning and operation
- **Space and Aerospace Applications /Test :** Test space components-systems: based on infrared imaging. New space applications supported by new generation of infrared detectors. Thermal testing components on earth e.g. thermal cycle test , vacuum test, balance test; Others considering space environment (thermal test that simulate the harsh conditions of space) or launch conditions. Control rocket's motor housing thermal protection. Control nozzle design… others (28) (52)
- **Spectrometry Near-Infrared NIR + Short-Wave Infrared (SWIR) Spectroscopy :** (ranges 700 to 2500 nm - many applications) Materials can be identify by their infrared spectral signatures. Objects/materials leave unique fingerprints crosswise the VisNIR spectrum range These spectral signatures enable identification of the materials for quantitative applications e.g., forensic analysis, precision agriculture, food industry processing, biomedical, environment analysis, mineralogy/geology, surveillance, astronomy, light research spectral analysis - noninvasive health monitoring and many more (SWIR included). Spectroscopic analysis of sample materials. Using the near infrared spectroscopy technique (Vis-NIRs ranges ~ 320 to 2500 nm) to detect COVID-19 disease in a pharyngeal swab sample taken with a swab through the nose or throat. (14)
- **Spot Welding (RSW) and Seams:** controlled by thermal imaging cameras /systems. Continuous or intermittent system (1)
- **Steam Traps Inspection:** with thermal imaging and supplemented with ultrasonic (passive) testing
- **Stress and Fatigue Analysis:** infrared thermography applied – TSA / fatigue limit
- **Structural Health Monitoring (SHM):** With thermal imaging in addition to other sensors for analysis - Meteorological factors and direct sun exposure of the analysis areas. Sensors designed specifically for geotechnical and structural monitoring applications. Mechanical phenomena are accompanied by ⇔ thermal effects. Thermomechanical analysis (strain mapping and fatigue detection), e.g. Damage detection and characterization by stimulated thermography (41)
- **Steel Industry:** Thermal imaging and thermometry: rolling mill, die forming, continuous casting and wire drawing machine (42)
- **SWIR Applications:** Dental, art inspection, recycling, semiconductor industry, SWIR backside or frontside wafer alignment (silicon -Si- wafers). Various industrial applications. Improves the visibility of objects that have built-in moisture. Remote sensing of flora. Level in opaque bottles, Military, Moisture detection (27)
- **SWIR Pocket Scope:** Image through haze, dust and smoke. To find targets faster. Compare with other viewer technologies thermal, visible, thermal, night vision (I2) systems (Binoculars – Monocular) (32) (42)
- **Tanks and Silos:** level monitoring with handheld or fixed thermal or VIS camera 24/7
- **Target Automatic Recognition (ATR)**: Ability for an algorithm to recognize targets. Detection and tracking algorithms. Forward looking infrared. Deep learning. Machine learning - In-library and out-of-library targets and irresolute / blurred objects - e.g. matching VIS + thermal imaging   (33)
- **Technical Surveillance Countermeasures (TSCM):** to find hot spots / hazards generated for different sources with thermal imaging

- ⇨ **Telecommunications:** Monitors infrastructure in cell towers, others thermal imaging cameras. Line scanners InGaAs = Light loss in optical network components. Multi-channel optical power monitors
- ⇨ **Terahertz (THz):** Passive & Active imaging -- Imaging through objects (security) & NDT
- ⇨ **Thermal Imaging Cameras /systems for monitor's 360° (+ PTZ):** Panoramic sights. Indoors -Outdoors as appropriate and potentially integrated with visible camera: wildlife parks, correctional facilities (prisons /jails), ancient monuments, electrical facilities, airports, ammunition warehouses (indoors / outdoors) shipyards, industrial companies, petrochemical plants, museums, military bases, hospitals and health centers; education (colleges, institutes, and universities) infrastructure recreation (parks and gardens), smuggling, storage depots and warehouse, recycling centers, non-military governmental, warehouses, data centers others (10) (25)
- ⇨ **Thermo-Fluid Dynamics:** studies with thermal imaging cameras /systems
- ⇨ **Thermoforming Process:** Thermography systems for boosting product quality. Thermal imaging for control plastic-sheet heating. Thermoforming challenges control by thermal camera. Consistent temperature profiles during the thermoforming process means quality at the end. Molded parts: find hot spots or cold spots to production quality adjustment
- ⇨ **Transformation Visible Camera (VIS ⟹ SWIR):** into night vision devices in⟹ SWIR band
- ⇨ **Tornado Research-Analysis:** Tornadic cloud bases observed with SWIR sensors -cameras. Compare with VIS poorly visible tornadoes. Imaging with SWIR through the atmosphere (54)
- ⇨ **Traffic Control:** Vehicle, bicycle, pedestrian with thermal imaging cameras / systems. Traffic security (e.g. thermal traffic sensor)
- ⇨ **Transportations Systems:** (asset) Tunnels-Verify Road conditions: asphalt - pavements . Thermal imaging cameras /smart systems-) See Dams - Bridge Deck - Road pavement / Monitoring (41)
- ⇨ **Turnkey for Different Projects:** Thermography tests or thermal imaging analysis required (+ other tests) for the Provisional Acceptance of an industrial, energy, building / other turnkey project. Performance in general must be verified on a case-by-case basis for an additional period till Final Reception of the Project
- ⇨ **Tyred & Brakes:** thermal imaging control fleets of heavy-vehicle inspection: large trucks in infrastructure and mining works
- ⇨ **Ultraviolet Imaging System:** for Skin and Sunscreen. Handheld ultraviolet imaging system for other applications. wavelengths less than 400 nm. Ultraviolet Germicidal Irradiation (UVGI).Source UV illumination (7)
- ⇨ **Unmanned Aerial Vehicles (UAV ⟹ part of UAS):** Fixed wing with EO cameras (e.g. infrared) with ground control station. Search and rescue missions (SAR) precision agriculture, volcanology earth science various applications, volcanology, landslide surveying. glacier monitoring, photogrammetry survey. UAV for the management of buildings reconstruction after an earthquake with photography and Infrared Thermal Imaging etc. UAV Forage mass monitoring with Vis-SWIR cameras. Hyperspectral cameras designed specifically for use on small unmanned aerial vehicles (UAVs), to monitor the details of spatial, temporal, and spectral representation of ground objects . Mini Drones miniature UAV, small. Multi-Missions Airborne Drone. Management and mitigation of UAS threats. See Drones too (3) (4) (9)
- ⇨ **Veterinary:** Thermal imaging in Equine: hidden injuries and inflammation detection and prevention, lack of circulation, and muscle atrophy, nerve damage, scar tissue, circulatory disruption others
- ⇨ **Volcanoes Monitoring**: Fixed Infrared systems for continuous volcanoes monitoring and handheld infrared camera for intermittent volcanoes monitoring. Thermal infrared and hyperspectral imaging for characterization of the volcanic emissions
- ⇨ **Watercraft:** (ship-boat-vessel) mounted thermal Imaging system for navigational safety (e.g. in the dark of night) : passengers, goods, defense, research and fishing ships (11)
- ⇨ **Water Course Pollution Monitoring**: Thermography systems spill detection (e.g., oil spill). Remote sensing of water pollution. + use SWIR
- ⇨ **Weather Forecast:** Information and data from satellite. Thermal bands (radiometers) or measuring the earth / oceans surface temperature - reflected light and radiation . Forecast accuracy **-** Doppler radar (weather radar) Satellites to track cloud formations and large storms. Climatology - meteorology science (54)
- ⇨ **Web Textile Fabric** Machine Vision Inspection thermal cameras. near-infrared (NIR) illumination
- ⇨ **Weld Control**: vehicle body assembly robot spot weld monitoring - Plastic welding / reducing scrap (1)
- ⇨ **Wide Area Surveillance (panoramic):** infrared systems applications e.g. 360°. Real-Time panoramic/ Multisensory surveillance detection systems. See Thermal imaging cameras /systems for monitor's 360° (25)
- ⇨ **Wind Farm:** (wind park ⇔ group of wind turbines): checking system connections, gearbox, generator- turbines (horizontal axis and vertical axis) and blades (e.g. materials: resins of glass fiber reinforced polyester, glass fiber reinforced epoxy, carbon fiber reinforced others) e.g. NDT to the blades: passive an active thermography (IRNDT), visual, ultrasonic. Drones: visual or passive thermography test to find surface defects; then image processing
- ⇨ **Wildlife:** (parks & open land) animal survey, animal rescue, detection and hunting in the wild using thermal infrared systems (+SWIR passive) + vision devices using active near-infrared (NIR) illumination (10)
- ⇨ **3D -Three-Dimensional / Thermal Imaging:** Challenges panoramic solution thermal imaging. True 3D thermal image enhancement and analysis. 3D Modelling with thermal imaging. Number of cameras needed. Future in ADAS. Comparison with LiDAR (20) Three-dimensional thermal images with surface temperatures in them. 3D machine vision to guides robots

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