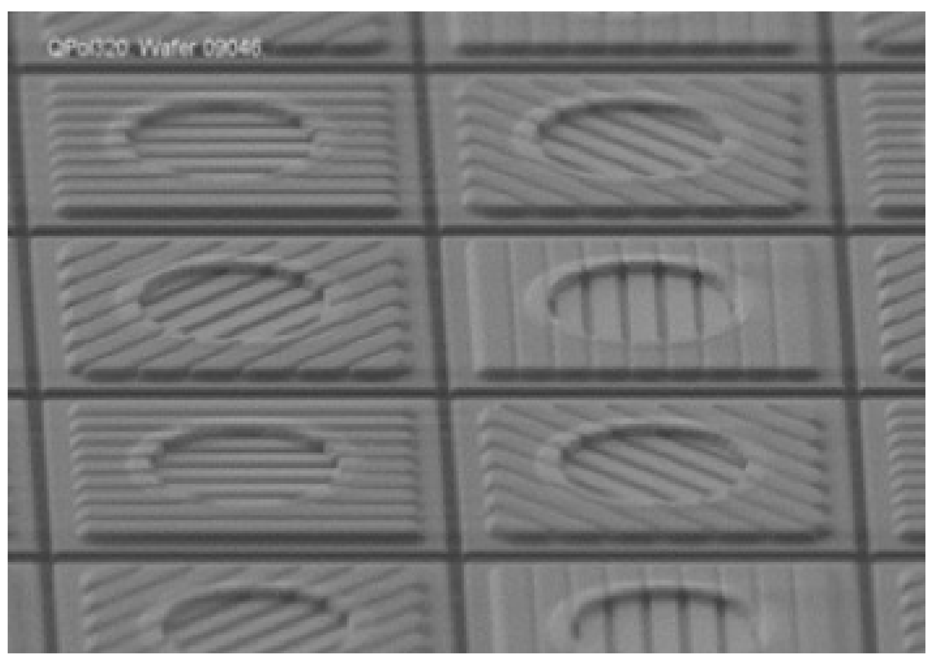
Polarimetric QWIP
Infrared imaging sensor

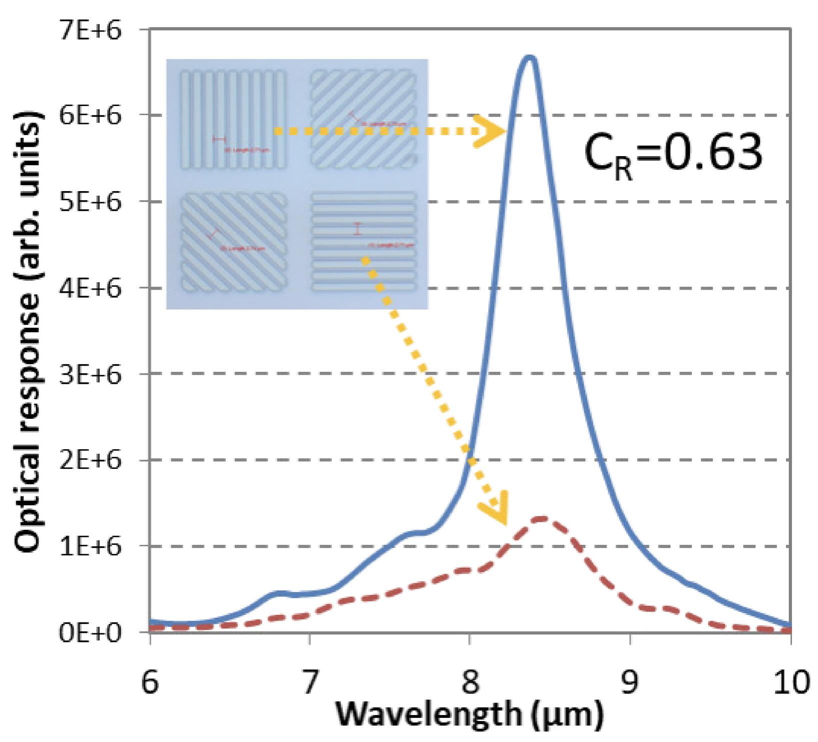
Introduction to polarimetric QWIP

Quantum well infrared photodetectors (QWIP) are by design inherently suited for polarization sensitive imaging. The detection principle in regular QWIPs relies on etched 2-D gratings to couple the light to the quantum wells for absorption. By replacing the 2D gratings with 1D (lamellar) gratings polarization sensitivity is added to the thermal detection.

The IRnova Garm LW Pol is a QWIP detector, which in addition to thermal imaging capability, is sensitive to the polarization of the infrared light. The sensor in the Garm LW Pol is equipped with fabricated gratings at the pixel level with four different orientations (0°, 45°, 90°, 135°). These gratings make each detector pixel sensitive to a specific orientation of the polarized light. By combining the information in each pixel with the four neighboring pixels, all information about the degree and angle of the linearly polarized light can be extracted and the resolution can be sustained.



SEM image of pixels in the polarimetric QWIP sensor with four different orientation of the gratings, which make the pixels sensitive to different polarization angles.



Optical response to linearly polarized light for two neighboring pixels with orthogonal gratings.

The responsivity of a polarimetric sensor to polarized light oriented in different directions can be described by a Stokes vector:

$$S = \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ 0 \end{pmatrix} = \begin{pmatrix} R_{0^\circ} + R_{90^\circ} \\ R_{0^\circ} - R_{90^\circ} \\ R_{45^\circ} - R_{-45^\circ} \\ 0 \end{pmatrix}$$

Where Ri refers to the responsivity of the detector in direction i. From this expression, regular thermal images can be extracted as:

- $I = \frac{1}{2}(S_0)$

while the degree of linear polarization (DOLP) and the angle of polarization (AOP) are calculated as:

- $DOLP = \sqrt{S_1^2 + S_2^2}/S_0$
- $AOP = \frac{1}{2}\tan^{-1}(S_2/S_1)$

Benefits of detecting polarization

Thermal imaging is a great way to detect objects, but it requires the objects to be of different temperature or to have different emissivity than the background. Polarization detection further extends the possibility to differentiate between objects that have the same temperature but consist of different materials, since infrared polarized light can be generated by reflection or emission of radiation from planar surfaces. This allows for detecting objects that are previously undetectable by an infrared detector since they may be covered under a canvas or they may have a low thermal signature like an UAV. Besides increased detection, polarization effect provides an exciting new information from planar surfaces: relative angle differences between adjacent surfaces. Adding a new set of information that weren’t accessing in infrared imaging so far.

UAV detection

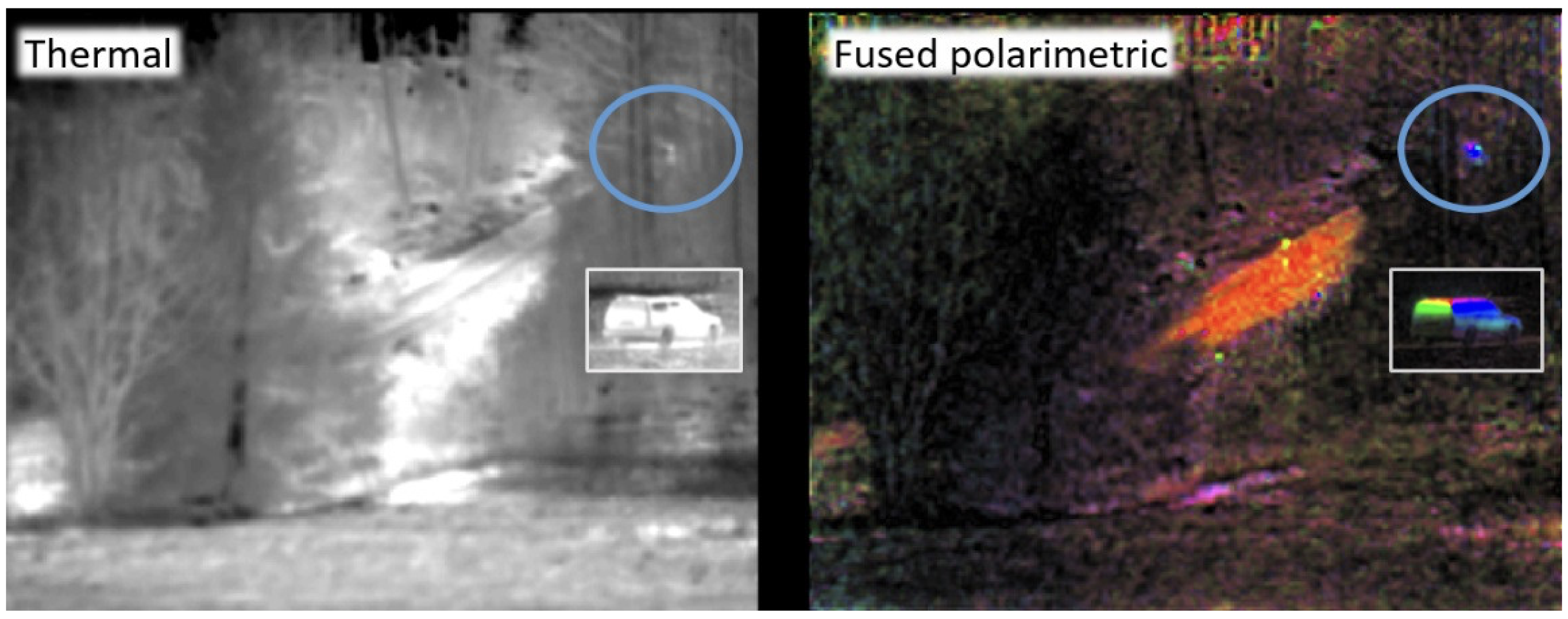
An UAV is hard to spot against surroundings with traditional thermal imagery as they are often small surfaces, equipped with insulated electrical engines with a very low heat signature. With polarization detection, as shown in the images below, the detector can differentiate the sources of emission and highlight the polarized reflection. This ensures a more robust detection of man-made objects that are invisible or near invisible with regular visible or infrared cameras.

Long range / small UAV increased detection

In this example, while the regular infrared camera couldn't detect the UAV due to the surface size and low contrast of the target, the Pol QWIP detector could easily detect a uniformly polarized surface triggering an unquestionable thread detection.

Camouflage denial

In similar ways polarization detection enables camouflage denial as the polarized detector distinguishes between man-made covers and natural ones. If an object is behind a natural cover It can still be spotted by the detector as it highlights uniform surfaces versus random natural ones.



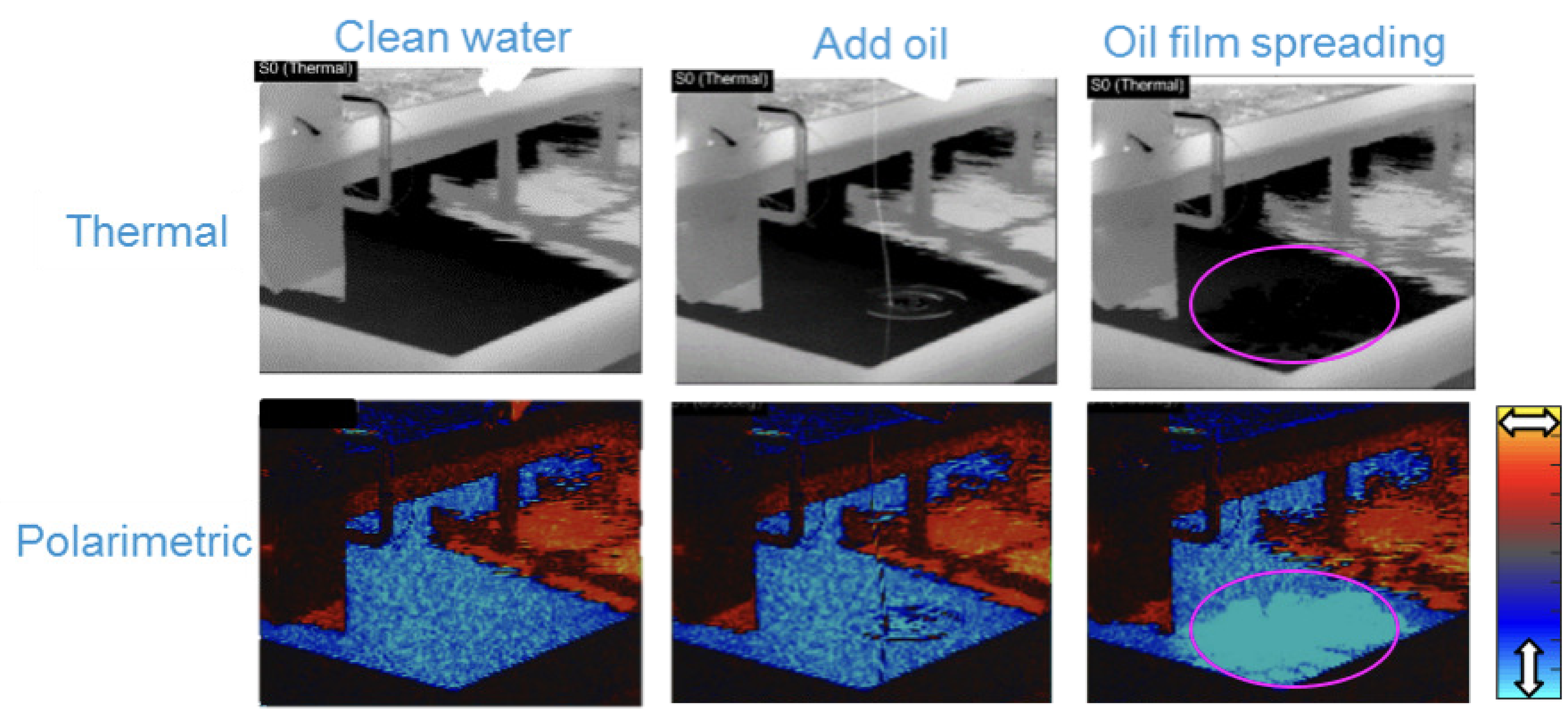
Camouflage denial amongst natural background

In this example, the vehicle behind the trees is hardly detectable as it can't be easily distinguished over the road background. The Garm LW Pol detector easily distinguished different polarization angles and spotted this anomaly, triggering the detection.

While having a closer look to the vehicle, its angled shape effects on polarization are easily measurable and clearly helps to even identify the vehicle type.

Oil spill detection

Polarization imaging can also detect the difference between the reflections on water and reflections from oil surfaces. In addition to the well-known advantages of cooled LWIR infrared for oil detection, Garm LW Pol can sense the oil surface uniform reflection, strengthening the oil detection capabilities and moreover extending the use for long range and/or bad weather conditions.

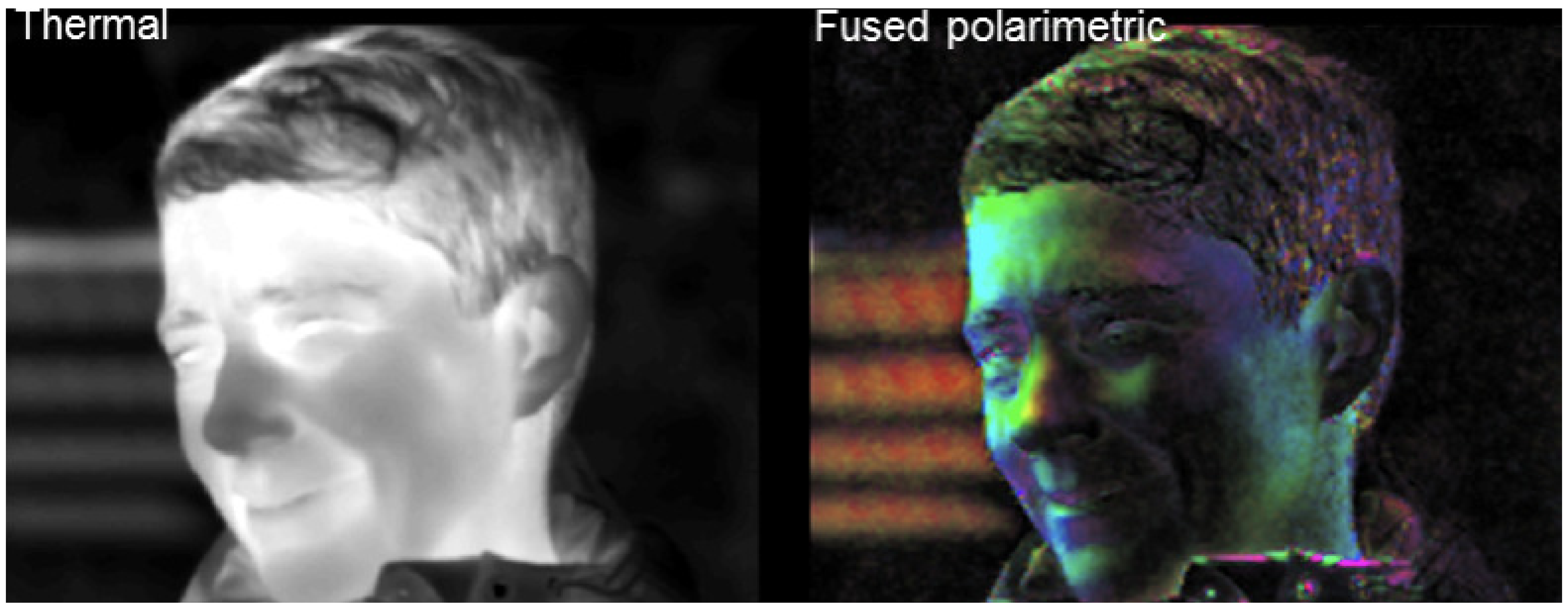


Oil spills detection

In this example, while the regular infrared image hardly detects the tiny amount of oil, the polarization effect of the oil is clearly visible in the polarized image.

Facial recognition

When adding polarimetric information to a thermal image for face recognition, additional contrast is achieved from the natural variation of angles and textures in the facial features. If processed, this information can result in an image that enables full facial recognition in light deprived conditions.



Infrared human face identification

In this example, Infrared radiated information isn't enough to identify humans. Using polarization information helps aping face angles and creating an exploitable face signature for computerized automatic identification.

Key advantages of polQWIP

Among all technics that can be implemented to sense infrared polarization information, PolQWIP detectors are by far the best option. It is also the first commercially available and affordable cooled detector solution.

PolQWIP is matching all requirements of deployed embedded systems, as the polarization sensing feature is not affecting the QWIP's genuine thermal capabilities: Field proven, highly uniform LWIR cooled infrared detector.

Polarization is not altering sensitivity, uniformity, size, weight or power consumption of the detector. PolQWIP detector is "plug and play" with any regular cooled LWIR detector in most of the fielded embedded systems.

There are other means of sensing infrared polarization, but a trade-off will be required between sensitivity, size, portability and more. Check below how PolQWIP is unrivaled:

	Filtered Bolometers	**Filtered cooled regular IDCA**	**polQWIP IDCA**
Sensitivity (1)		✓	✓ ✓
Frame rate (2)			✓
Field deployable (3)	✓		✓
Compactness (4)	✓		✓
Scalability (5)			✓
Spectrum coverage (6)		✓	
Cost (7)	✓		✓

Infrared human face identification

1. **Pixel sensitivity:** Many parameters can be considered to quantify "sensitivity" the approach here is a fair combination of commonly agreed parameters.
2. **Frame rate:** Quantifying the ability to make videos at high frame rate, aimed at scenes with relative high motion in the image (high speed targets or vibrating carrying platforms)
3. **Field deployable:** Quantifying the ability of the solution to embedded in regular fielded systems with harsh environment (chocs, vibrations, heat ...) with reasonable lifetime maintenance/servicing task.
4. **Compactness:** Quantifies the ability of the solution to be incorporated within standard fielded equipment like cameras (compatible in size, weight, power etc. ...)
5. **Scalability:** Quantifying the ability to replicate the same performance and production cost for larger arrays and/or smaller pitch (HD, 2K,4K ...)
6. **Spectrum coverage:** Both bolometers and cooled QWIP detectors are only operating in LWIR wavelength
7. **Cost:** Not only covering the detector cost, but the cost of the full solution (system level and lifetime ownership costs). Both bolometers and PolQWIP have different order of magnitude compared to regular filtered cooled solutions.