# Application note

## Detecting and Defeating Subversive Night and Fog Activities

*SWIR Cameras Ensure Visibility Day and Night in Any Weather*

Around-the-clock surveillance capability in any weather is a decisive operational ad-vantage for military and emergency services. In these and similar applications, SWIR cameras are well-suited for everyday use because they show superior results when compared with most other imaging technologies. To recognize and track objects of light-reflecting as well as thermal-radiating natures, SWIR cameras can be easily combined with thermal LWIR cameras and their images fused to enhance their content and validity.

**Imminent Danger**

Public order and security are permanently challenged. High-tech drones fly over selected targets often unnoticed to carry out their missions autonomously under remote control. Combat-like night and fog activities literally happen under the cover of darkness and night. All of these dangers are calling for effective countermeasures.

**Uncovering the Camouflage**

If an intruder attempts to penetrate the perimeter of a protected area, the threatening action must first be noticed and observed in detail, and the attackers and their possible targets identified before appropriate countermeasures are initiated. This often means their camouflage must be uncovered. This, of course, is easier said than done since atmospheric conditions for surveillance measures can vary widely, from glaring daylight of >100,000 lux to a dim twilight at dusk and dawn to total darkness in moonless nights and overcast skies with an illuminance of less than 0.01 lux.



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**Appropriate Window**

A reconnaissance system used day and night under all atmospheric conditions must meet all of these operational requirements. First to be decided on is the appropriate wavelength window with regard to the prevailing atmospheric conditions. This is not necessarily the visible spectrum, since a veil of haze could obscure objects far in the background or a smokescreen in the foreground could hide suspicious objects or persons *(figure A)*.

***Figure A:*** *in the visible spectrum, haze and fog are marring the view (top). SWIR cameras see through haze and fog (bottom).*



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Bordering on the visible realm is the shortwave infrared (SWIR) range, stretching from 0.9 to about 1.7 µm. Here, the impact of haze and smoke significantly reduces *(figure A, bottom)*. Similar to thermal imaging, image capture in the SWIR will miss the color content of the visible realm. However, SWIR images can be interpreted as easily and directly as those in the visible realm. Both SWIR and visible images are formed by light reflected off the objects observed. An added advantage of SWIR image sensors is their high sensitivity and wide dynamic range.

**Choice of Image Sensor**

After exploring the different wavelength bands with regard to their usability for optical reconnaissance, Singapore-based sInfraRed, a Xenics company, has taken an additional step together with one of their customers of investigating the suitability of various sensor technologies for this application. Several test series were carried out at various sites, at different times of day and night, and under clear skies, fog, and smoke. Four technologies were investigated:

- Residual-light amplifier (Gen. II image intensifier)
- Low-light CCD image sensors highly sensitive to visible light
- SWIR camera (0.9 to 1.7 µm) in InGaAs technology
- Uncooled micro bolometer for thermal LWIR image capture (8 to 14 µm)

The results are shown in *figure B*. Residual-light amplifiers excel under clear skies and moonlight. Airglow, or atmospheric night glow, centers primarily around a wavelength of 1.6 µm, which makes it very interesting for SWIR imaging. However, the stark contrast between artificial light sources encountered in urban environments can blind the sensors of residual-light amplifiers. The same will happen in bright daylight.



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| Weather \ Camera | Thermal | SWIR | CCD/ CMOS | Image Intensifier |
|---|---|---|---|---|
| Bright Day | ✓ | ✓ | ✗ | ✗ |
| Overcast Day | ✓ | ✓ | ✓ | ✗ |
| Light Fog | ✓ | ✓ | ✗ | ✗ |
| Hot/Humid Day | ✗ | ✓ | ✓ | ✗ |
| Urban Night | ✓ | ✓ | ✓ / ✗ | ✓ / ✗ |
| Full Moon | ✓ | ✓ | ✓ | ✓ |
| Stars | ✓ | ✓ | ✗ | ✓ |
| Overcast Night | ✓ | ✗ | ✗ | ✗ |
| NIR Marking | ✗ | ✓ | ✓ | ✓ |
| Hidden Marking | ✗ | ✓ | ✗ | ✓ / ✗ |

***Figure B:*** *Suitability of various imaging technologies as reconnaissance tools*

Somewhat larger is the dynamic range of CCD and CMOS imagers. Operating in the visible portion of the spectrum, they tend to degrade in haze and fog. Also, their sensitivity is not sufficient in dark nights with just starlight present.

The large dynamic range of SWIR imagers, which suits them well for many applications, is determined by three favorable parameters: InGaAs detector technology offering dynamic, overdrive-resistant exposure control, atmospheric transparency despite haze and smoke, and the benefit from airglow illumination, an atmospheric phenomenon occurring in clear skies, which extends far into the SWIR range up to about 1.6 um. At this wavelength, airglow is much stronger than moonlight in terms of the photons emitted. Nevertheless, a SWIR camera will reach its limits at night with overcast skies, with no airglow present.

LWIR thermal cameras respond to the thermal emission of objects. They are usable in moonless nights and at overcast skies since they don't rely on any light sources. However, as mentioned before, on hot days, their performance can be affected by high atmospheric humidity.



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**SWIR Reconnaissance**

*Figure B* shows how the various imaging technologies measure up as reconnaissance tools in a variety of conditions. In a second test series sequence undertaken by sInfraRed and a customer, their performance was quantified and compared to establish the validity specifically of SWIR cameras for reconnaissance purposes. The SWIR camera tested was equipped with an InGaAs sensor array of 640 x 512 pixels and 20-µm pixel pitch. It featured TE1 cooling and was fitted with a custom-made 100 mm SWIR lens.

The quantitative results under four typical weather conditions are summarized in *figure C*. The SWIR sensor takes a high ranking in comparison with its competitors: uncooled thermal LWIR sensor, CCD camera, and image intensifier. SWIR takes first place six times and second place six times as well. There is no other camera technology reaching a better position.

| Weather | Detection | | Recognition | | Identification | |
|---|---|---|---|---|---|---|
| Bright day | 1800 m | ○ ● ○ | 1600 m | ○ ○ ● | 670 m | ○ ○ ● |
| Humid/ hot day | 1700 m | ○ ○ ● | 1500 m | ○ ○ ● | 700 m | ○ ○ ● |
| Full moon Slight fog | 1200 m | ○ ● ○ | 900 m | ○ ● ○ | 700 m | ○ ○ ● |
| Overcast moonless night | 300 m | ○ ● ○ | 255 m | ○ ● ○ | 95 m | ○ ● ○ |

Ranking: ● 3. best ● 2. best ● best

Competitors: thermal LWIR uncooled
Low light CCD
Image intensifier

***Figure C:*** *Test results of a SWIR camera at different weather conditions*

The outstanding performance of SWIR technology is seen in *figure D*. A person, assumed to be a combatant, is approaching to about 40 meters. Obscured by a smokescreen, he is invisible to the human eye but recognized by the SWIR camera to be safely repelled.



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***Figure D:*** *To the human eye, the person is invisible. A SWIR camera sees through darkness and smoke.*

**Two Sensors See More**

As mentioned, a SWIR camera will reach its performance limit in a moonless night and overcast sky, so image capture would benefit from a second camera in parallel, which additionally covers the LWIR thermal band. Xenics has developed a family of high-resolution SWIR and LWIR camera modules called XenicsCores. Based on a common electronics platform, they can be easily combined and integrated according to their intended use.

*Figure E* shows the SWIR module XSW-640 along with its technical data, and the thermal LWIR module XTM-640. Both are lightweight at less than 100 grams and consume less than 2 watts on a 3.3V power supply. They deliver parallel images according to their spectral areas, which can be overlaid and fused to a spectral composite with increased content under all weather and light conditions.



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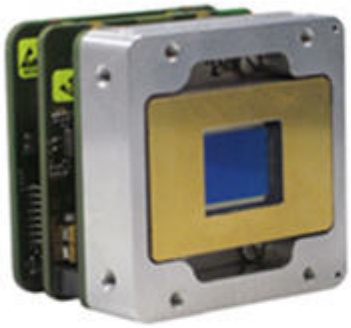

**XSW-640 Key Features**
TE1 cooled InGaAs array
640 x 512 pixels
0.9 (optional 0.4) to 1.7 µm bandwidth
20 µm pixel pitch
50 Hz framerate
49 x 49 x 34 mm
Samtec 40 pin QTE interface

**XTM-640 Key Features**
Uncooled microbolometer
640 x 480 pixels
8 to 14 µm bandwidth
17 µm pixel pitch
50 Hz framerate
45 x 45 x 34 mm
Samtec 40 pin QTE interface

***Figure E:*** *High-resolution SWIR camera module (top) and thermal LWIR module (bottom) are easily combined for image fusion.*

**Conclusion**

SWIR cameras yield good results at any weather condition, day or night. They are well-suited for reconnaissance tasks of all kinds and are an important contribution to public order and security.

**About The Author**

Raf Vandersmissen is CEO of sInfraRed Pte Ltd, Singapore – a subsidiary enterprise of Xenics nv, Leuven, Belgium.



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