Why Polarimetry?

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Background: Why Thermal Polarimetry?

Polarization signatures, especially in the LWIR, are often not well understood. The following are a few example images that show the reasons that polarization sensing when added to standard thermal imaging has significant benefits.

In a polarization image, a man-made object has a unique signature compared to the natural surrounding clutter which makes the man-made object stand out. **Figure 1** compares a thermal image (on the left) to a thermal plus polarization image (on the right). The images were captured by a Pyxis LWIR polarimeter integrated onto a Puma UAS drone flying over a test range in Simi Valley, CA. Several plates painted with military CARC paint, and other manmade objects were positioned in locations that are difficult to see with a thermal-only imager. For example, the painted plates positioned in the shade lose thermal contrast (they have no solar loading) and blend into the background of the thermal image. However, in the polarization image, the targets stand out. The polarization contrast comes from emission differences between orthogonal polarization states that refract out of the metal surface.

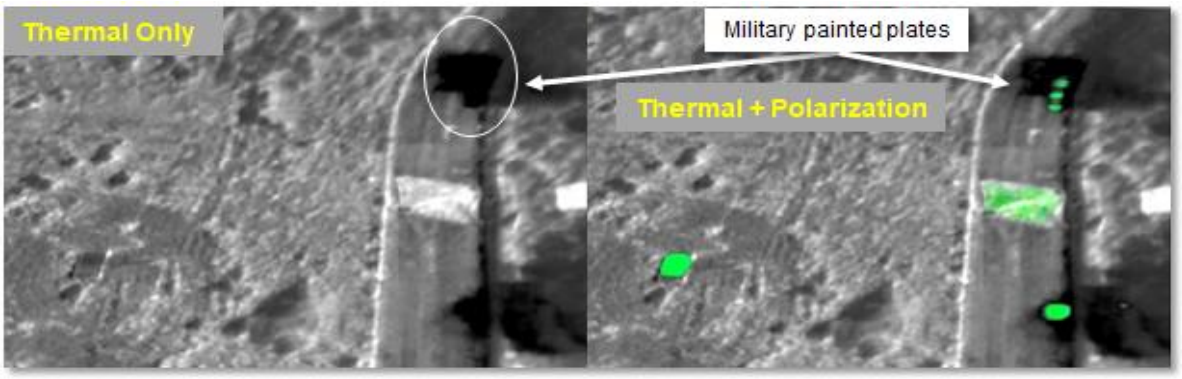

Figure 1. Thermal (left) vs Polarimetric (right) in Clutter and Low-Contrast Conditions.

Partially obscured targets are also a challenge for thermal-only seekers. For example, if a military vehicle is parked under a large tree, detection and discrimination can be impossible. If there are openings between the leaves, then frequently the polarization signature of the vehicle will be visible through the openings. **Figure 2** shows an image taken by the Pyxis LWIR of a truck hidden behind a tree. The left image is the thermal image, the center image is the polarization image, and the right image is the thermal plus polarization image. Note that the truck outline, although partially obscured, is clearly visible in the polarization image behind the tree.

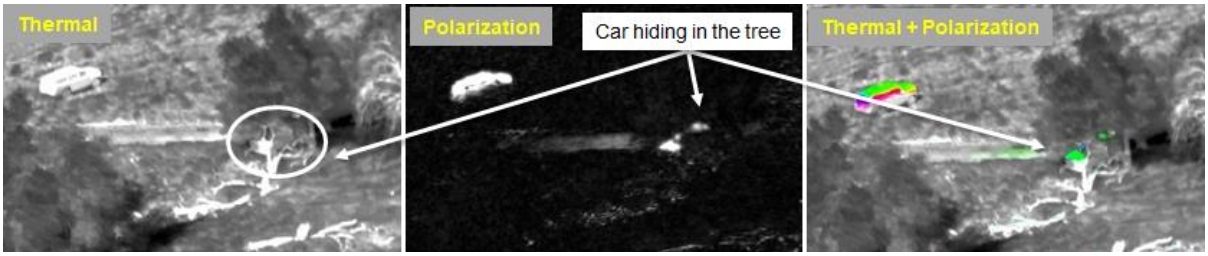

Figure 2. Thermal (left), Polarization (center), and Thermal + Polarization (right) of a Truck Behind a Tree.

Detection at long standoff distances is even more difficult when only a few pixels are on target. **Figure 3** compares thermal (left) and polarization (right) images captured from Pyxis LWIR on a Puma attempting to acquire an under-resolved man-made target in natural clutter. Objects are very difficult to find in the thermal image even when the observer knows what and where to look for them. In the polarization image, the background natural clutter is suppressed, and the man-made objects are very easy to detect. If the man-made objects are not moving, then detection in a thermal image is impossible and polarization capability is essential.

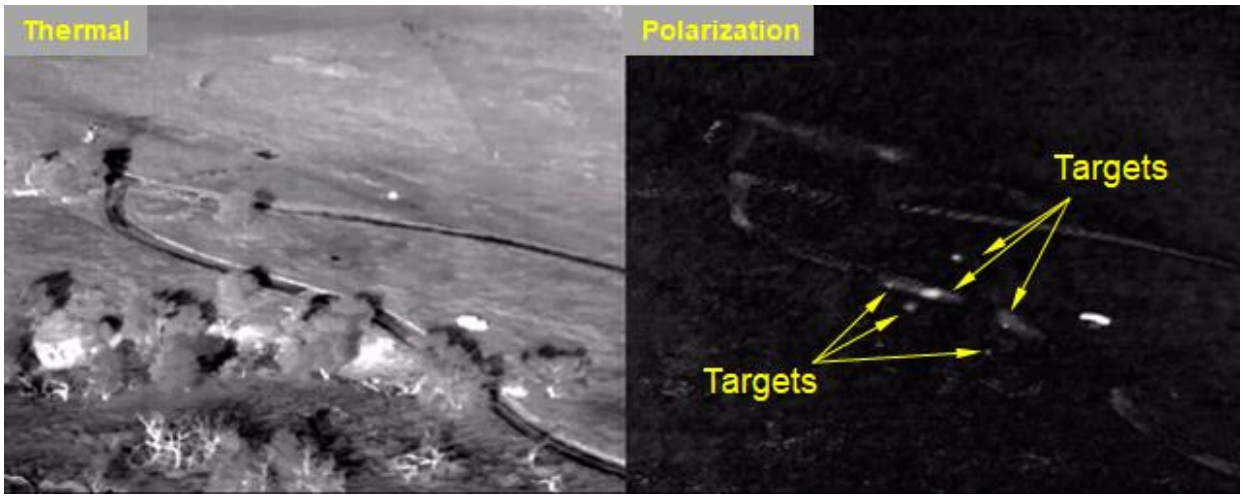

Figure 3. Under-Resolved Targets in Thermal and Polarization Images.

Besides the problem of detecting man-made targets in clutter, another challenge for thermal imaging is low thermal contrast conditions, especially during thermal cross-over periods. In this situation, the target of interest has reached the steady-state temperature of its surroundings, and its apparent temperature matches the background. Even for well-resolved targets, the spatial frequencies and apparent temperature of the target can match the background, and the object completely blends into the background, as shown in Error! Reference source not found..

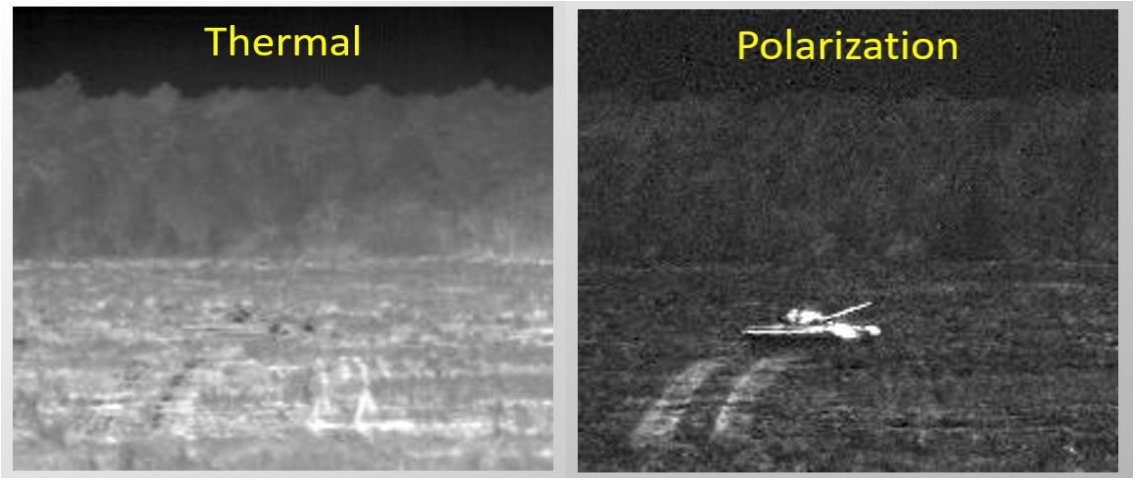

Figure 4. Thermal and polarimetric image of a tank during a thermal cross-over period.

When looking for threats on the ground from a vehicle or dismounted soldier, polarization sensing is often essential for detection. **Figures 5** and **6** show example Pyxis images of two butterfly mines, one clearly visible on concrete and the other in high clutter (grass/leaves). In the thermal image (**Figure 5**) the butterfly mine is clearly visible on the concrete, but a second one is "hidden" in the grass. In the polarization image (**Figure 6**), the second butterfly mines is clearly visible.

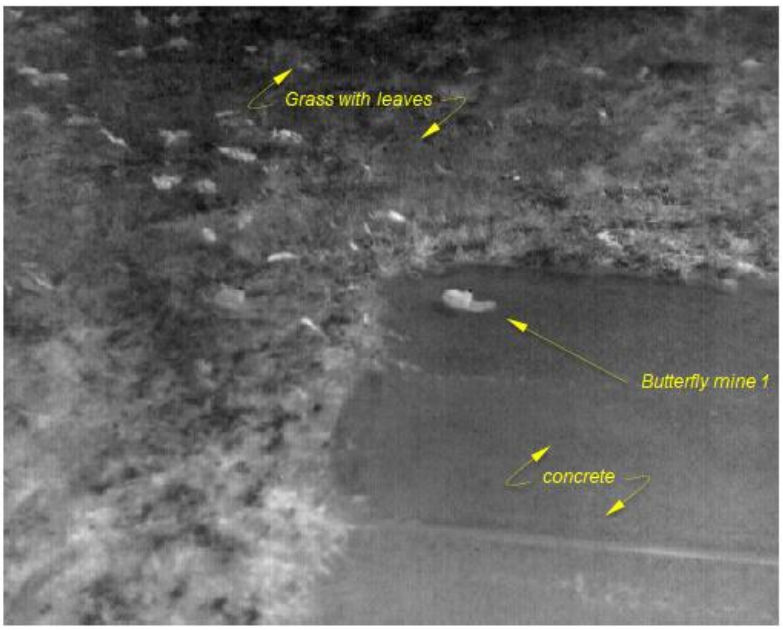

Figure 5 Pyxis Thermal Image of butterfly mines on concrete and grass

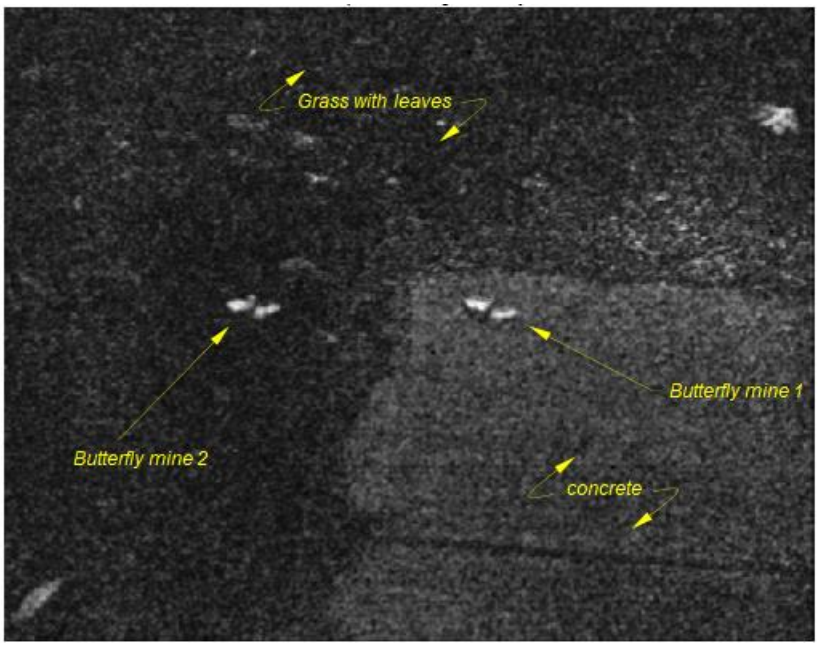

Figure 6 Pyxis Polarization DOLP Image of butterfly mines on concrete and grass

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Figures 7 compares thermal and polarization images of several man-made objects from a 300' altitude. The objects are "hidden" in grass, weeds, rocks and dirt, and the image is captured at nighttime when target temperatures are close to the ground temperatures.

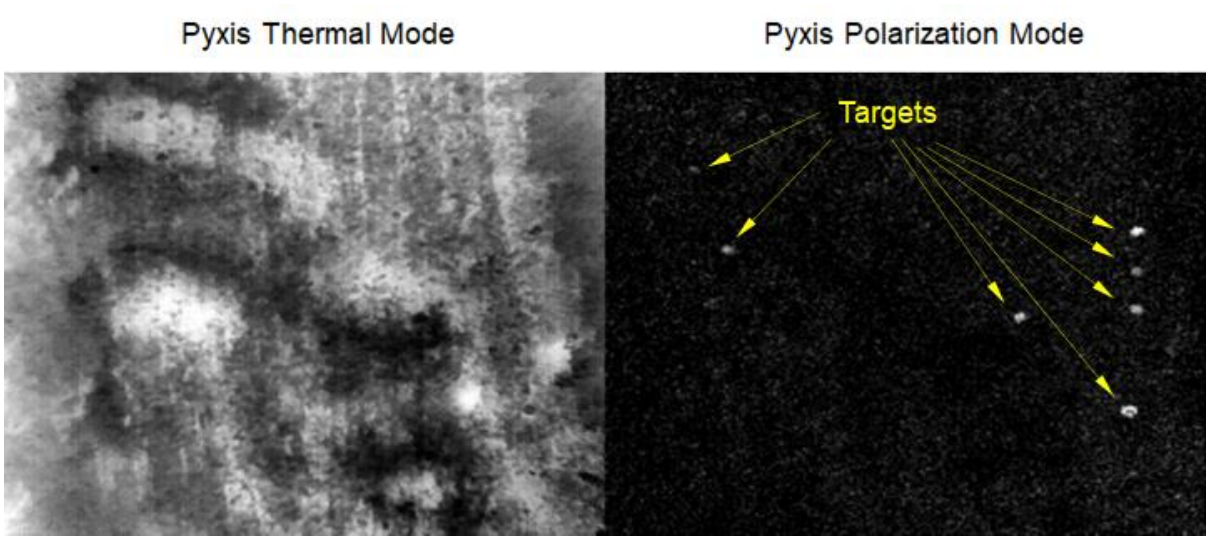

Figure 4 Thermal and polarization images captured of manmade targets in grass from 300' tower Redstone Arsenal, AL

In the thermal image, the apparent temperature and structure of the targets blend into the background. In addition, the number of pixels on target are limited due to the object size and drone altitude. Clearly without the secondary mode of polarization sensing, most if not all the targets would go undetected. It is important to note that at other times of the day, such as when the targets are in direct sunlight, the thermal mode of Pyxis can find targets better than in polarization mode.