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Materials for infraredand visible vehicle identification from surveillance aircraft

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A new family of marking materials allows unambiguous identification of military, police, and other emergency service vehicles by surveillance aircraft.

Civilian law enforcement officials consider airborne surveillance a highly effective tool for preventing and detecting crime, as well as for supplying evidence to support criminal investigations.[1] Most police forces have their own dedicated aircraft fitted with a combination of visual and thermal InfraRed (IR_T) imaging equipment to give them day and night-time surveillance capabilities.[2] Police ground vehicles have visible alpha-numeric and symbol roof markings, but these are not detectable by the IR_T imagers that are used on police aircraft at night or in poor visibility. This is because the materials currently used for roof markings have low reflectivity to IR_T and so they do not produce the high contrast needed to produce clear IR_T images. Consequently, police cars are indistinguishable from each other or from similar civilian vehicles in these situations.

The present-day practice is to request that police vehicles identify themselves to the air surveillance platform: by opening the vehicle windows and waving, for example. Our approach is to create visibly black films with high IR_T reflectivity,[3] to be used in combination with conventional sign-writing vinyl appliqués. When placed on the top of a vehicle, the high IR_T reflectivity shows as black (cold), while the conventional material shows as white (warm). The technique relies on making the background of a marked area of the vehicle roof appear significantly cooler to an IR_T imager than the surrounding vehicle surfaces, foreground symbols, and environment. Since the IR_T apparent temperature of the sky is usually significantly lower than the environment below, we use cold-sky reflection to form a high-contrast area onto which symbols can be placed.

Figure 1. *Visible and* IR_T *images (3-5μm) of a vehicle marked with the new Mirage™ material.*

Developing the approach

The simple Stefan-Boltzmann law gives the radiant energy (E) of a body as $E = \varepsilon\sigma T$,[4] (where ε is emissivity, σ is Boltzmann's constant, and T is absolute temperature), and Kirchoff's law teaches that for an opaque body $\rho = 1 - \varepsilon$, (where ρ is reflectance). Hence, a high-IR_T-reflective surface facing the sky and viewed from above will appear cold because of the re-

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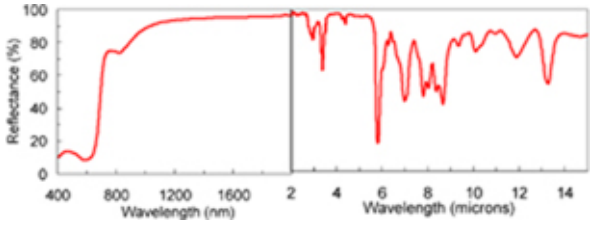

Figure 2. *Reflectance spectrum of a black high-IR_T-reflective film formed from a visible to near-infrared spectrum (400 to 2000nm) and an infrared spectrum (2-15μm).*

duced thermal radiance of the surface and the reflection of the 'cold sky.'

Conventional vinyl sign-writing films have low IR_T reflectivity and, when placed on a vehicle roof, appear warm. Their self-radiance is high and there is little cold-sky reflection. Symbols can be cut from vinyl films and applied on top of the high-IR_T-reflectivity film to form unique IR_T vehicle markings, an example of which is shown in Figure 1. Symbols also can be cut directly from the high-IR_T-reflectivity film and placed on white-painted roofs to make a black-on-white IR_T marking.

To maximise IR_T contrast (and thus the readability range) and to achieve compatibility with the current visible markings, a visibly black (with reflectivity between 400 and 780nm less than 10%), IR_T reflective (reflectivity between 3-5 and 8-12μm greater than 80%) material is desirable. We have explored several approaches that trade properties such as reflectivity spectrum, durability, weight, cost, etc., to form a family of marking materials. Figure 2 presents a composite reflectance spectrum of one of the materials developed for this application.

To optimize the appearance of the markings (character fonts, contrast, and dimensions) for different situations (such as classes of vehicles, operational altitudes, look-down angles, and imager types), a series of experiments was conducted in collaboration with police surveillance units in the United Kingdom.[4] Figure 3 shows ground-to-ground imagery of a heavy goods vehicle prepared for experimentation. Note that, in this case, high IR_T letters have been applied onto a conventional white vinyl marking film. The low IR_T black marking film was also applied to the shoulders of a high-visibility jacket. Figure 4 presents IR_T images of two subjects, one with the film and one without.

Conclusions

The cold sky reflection technique and the materials described here provide an effective technique for unambiguously monitoring military, police, and other emergency service vehicles from the air by using visible and IR_T imagers. They are effective on personnel, as well as vehicles carrying high value cargoes.

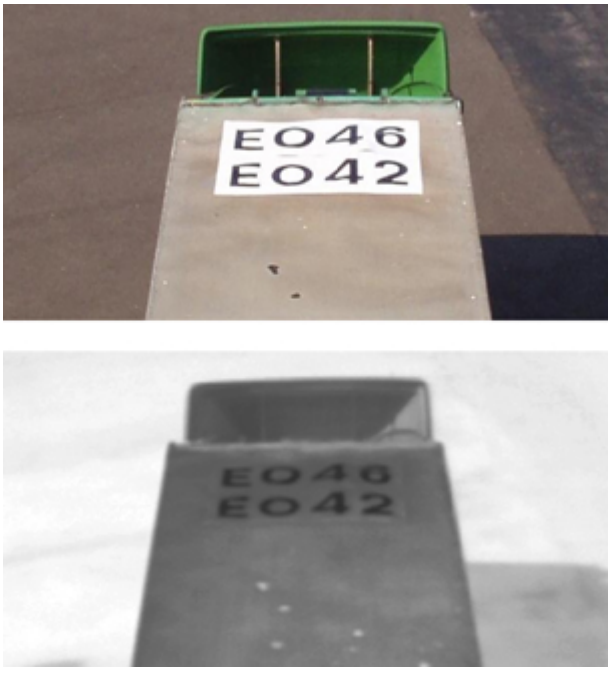

Figure 3. *Visible and* IR_T *(8-12μm) images of a heavy goods vehicle marked with 360mm high* TransportHeavy *font letters and numbers cut from Mirage™ vehicle marking film on a conventional white vinyl background.*

Figure 4. IR_T *(8-12μm) images of subjects wearing Mirage™-marked (left) and unmarked (right) high-visibility jackets.*

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