THERMAL IMAGES ANALYSIS – DETERMINANT FACTOR IN DECISION MAKING

Lieut.eng. Cornel TODIRICĂ, *Military Equipment and Technology Research Agency – METRA*

Prof. Emil CREŢU, PhD, *Titu Maiorescu University*

Lieut.eng. Daniel ŢURCANU, *Military Equipment and Technology Research Agency – METRA*

Eng. Niculae GUZULESCU, *Military Equipment and Technology Research Agency – METRA*

ABSTRACT:

Each target has got a unique thermal signature which is, with some reservation, possible to identify and classify. By analyzing thermal signature the decisionmaker can react in an advantageous manner to his interests or objectives. By analyzing the thermal signature a target can be recognized and one could tell if it is a real or a decoy target.

keywords:determinant factor, thermal images, thermal signature

INTRODUCTION

Thermal Imaging uses infrared technology to detect small differences in temperature. Every material has a unique thermal signature and when moisture, heat, cold or material failure are introduced the thermal signature changes. The changes can be subtle or dramatic but with a trained inspector and this technology they are detectable where they wouldn't be able to be seen with the naked eye. This is used in conjunction with other technology and experience to help identify issues and concerns during the inspection process.

In today’s advanced military operations, the concern for protection and survivability has increased, due to the increasingly diverse and asymmetric environments in which these operations take place. In the past, armored vehicle survivability has relied largely on penetration avoidance. Today, we are addressing the survivability technologies developed, to meet the objectives of detection avoidance, hit avoidance, penetration avoidance and advanced situational awareness.

Thermal imaging (TI) systems can indicate the presence of, or recent presence of enemy forces. Even an empty airfield can show signs of recently departed aircraft due to the heat generated by their engines: the heated tarmac showing up as a TI signature quite clearly.

For observation with thermal imagers it is the difference in target and background temperature that causes the contrast. Different from visual (reflective) contrast the difference in temperature is not caused by the properties of the surfaces alone, but rather a number of properties of the bulk material as well as the influences from the environment, the weather conditions. The temperatures in the nature vary fast with the weather conditions and time of day, and different materials like rock and grass changes temperature differently. This causes the temperature differences (the contrast) also to change fast.

THERMAL SIGNATURE COMPONENTS

Each of the equipment items, if not protected, emits a set of signatures because of its design and configuration. Although this set of signatures is unique to the equipment type, each of signatures can be described generically to assist in devising protective techniques.

A first component of the thermal signature is that caused by internally generated. Engine exhaust gases are led through a muffler system to open air. In all cases there is a resulting exhaust gas “plume” whose size and temperature varies with the size of the engine. In most cases the muffler system is exposed to the air and is in itself a detectable signature. Radiators by their nature are exposed to the air and thus also present detectable signatures, although not of the magnitude of the engine or exhaust.

Most tacked vehicle and many communications systems are equipped with small power units auxiliary to the main engine, to permit low-power operation of communications equipment. Such auxiliary power units do generate thermal signature, but they are of concern primarily at night, when all other elements of the system are quiet and cool.

A second component of the thermal signature is that caused by exposure to the sun. The effects are solar heat loading and diurnal variations. The solar heating phenomenon begins with the fact that most mobile tactical equipment is first, made of metal, and second, is dark in color for camouflage reasons. As a result, when such equipment is exposed to the sun, it absorbs heat quickly and retains the heat throughout exposure. The speed and degree of heating are directly related to the construction of the specific equipment.

A third component of the overall thermal signature of a military unit is influence of equipment on the adjacent ground and air. Ground tracks, exhaust emissions, and dust clouds are the major considerations.

As the mobile equipment items transit their area of operations, wheels and tracks impinge upon the ground and disturb the ground surface. This action results in a heated ground track, which can be detected by thermal sensors after the passage of the equipment, in addition to its availability as a classic visual cue to military activity.

When the transit is made under dry condition, it is also common that the movement action generates dust, which is thrown up into the exhaust cloud and floats with it. Depending on air temperature and wind conditions, this exhaust gas/dust cloud can linger in the area and present a thermal signature after passage of the equipment.

Fig.1 – Examples of thermal signatures (helicopters, helicopter on the ground, truck)

Thermal signature almost always results from the difference, or contrast, between the target and its immediate background. Imaging sensors see internal target detail and external shape detail. Therefore, target signatures are defined by their pattern features. Those features are unique only to the extent that their proprieties differ from those in the background. Thus, resolved target signatures depend on background intensity mean values as well as on clutter intensity variations on a size scale comparable to internal target detail. Background spatial, spectral, and intensity characteristics are key to target signature generation and signature suppression.

EQUIPMENT

For the measurements and analysis presented in this paper it was used a system specially developed for heat transfer analysis.

The system has the following capabilities:

- target detection, recognition and identification;
- radiometric parameters analysis;
- high speed image recording;
- thermal signature evaluation in 3,0÷5,0 µm and 8,0÷12,0 µm spectral domains.

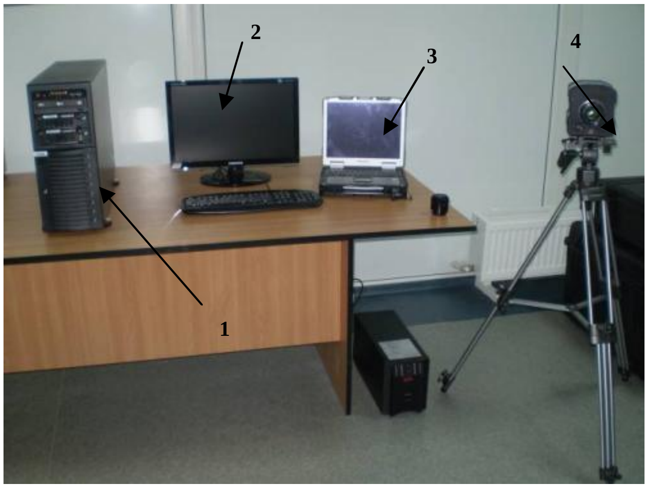

Fig.2 – Thermal signature analyzing system

The main components of the system are:

1.a. High speed data recorder:

- radiometric data recording at rates up to 50MegaPixel per second without losing frames;
- recording full camera data rates to removable, nonvolatile storage for up to one hour;
- real time image display capability while recording;

1.b. RTools Software for real time data analysis. The RTools software is a modular software package developed for engineers and scientists to acquire, radiometrically calibrate, process, and analyze data from various digital infrared camera systems. The RTools toolkit is comprised of:

- RDac - Real-time Data Acquisition Program
- RCal - Radiometrically Calibrate Infrared Cameras
- RView - High-performance, Data Viewing & Analysis Module
- REdit - File Archival, Editing and Maintenance Tool

2. Monitor;
3. Fully ruggedized Laptop for field data acquisition;
4. FLIR SC6000QWIP and FLIR SC 4000HS thermal imagers;

• Detector:	QWIP/InSb
• Spectral range:	8,0 – 9,2 µm/3,0 – 5,0 µm
• Resolution:	640 x 512 pixels/ 320 x 256 pixels
• Detector size:	25x25 µm
• Scanning rate:	35.000 cadre/sec
• NETD:	< 0,035K
• Operating temperature:	-40...+50°C
• Lens:	25 mm and 50 mm / 13mm and 100mm

ANALYSIS

The detection represents the first level of observation and assumes that something is seen in the visual field of the optoelectronic device, something that is different from background and shows interest for the observer. Detection range represents the measured value from observation point to target in the visual field of optoelectronic device.

The observation stages are: detection, recognition and identification.

The detection process can be separated into four independent primary areas, which can be characterized as follows:

- Target-to-background radiation contrast
- Attenuation processes
- IR systems
- Countermeasures (camouflage and smokescreens)

Information on parameters related to targets, backgrounds, sensor systems, and atmosphere must be obtained:

- to validate model calculations,
- to determine detection and especially identification clues on the target,
- to train automatic target recognizers (ATR),
- to develop countermeasures, for design purposes and as input for simulation models (operational research).

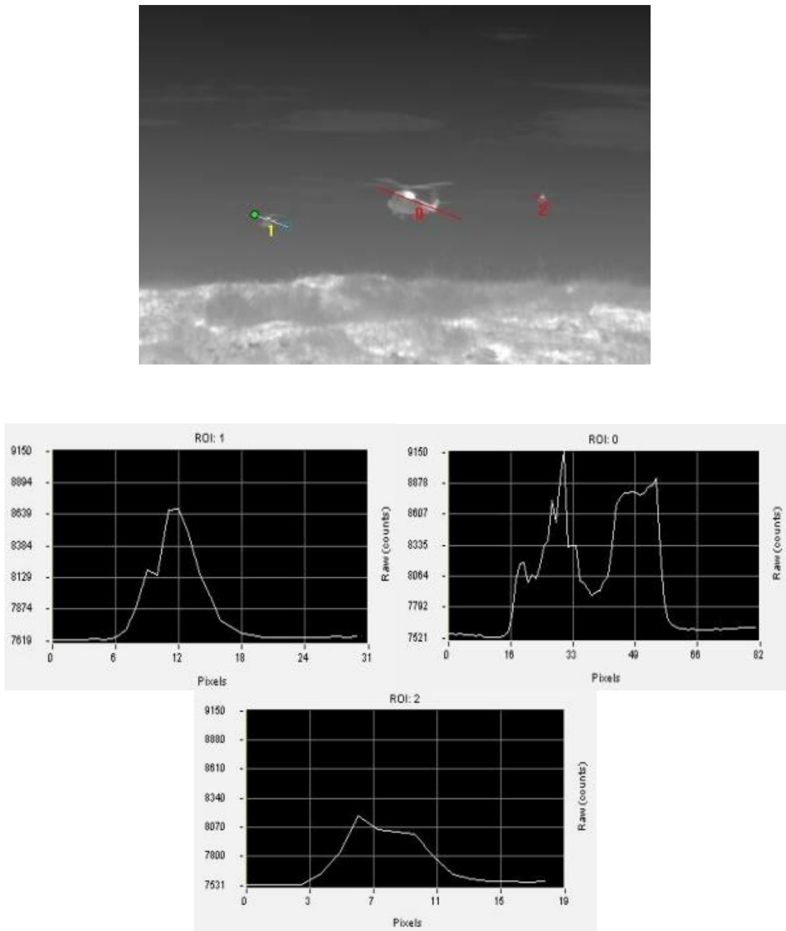

Fig.3 – Thermal signature for three helicopters at different ranges (1 -100m, 2-300m, 3-500m)

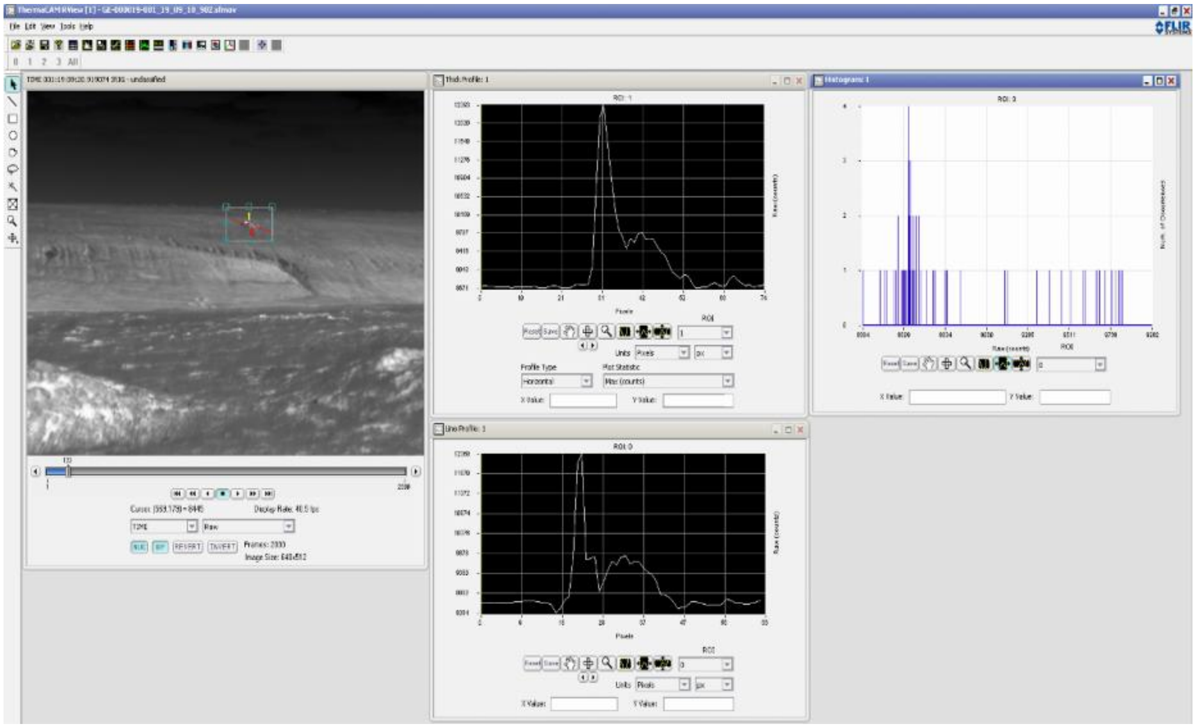

Fig.4 – Analysis of a helicopter at low altitude

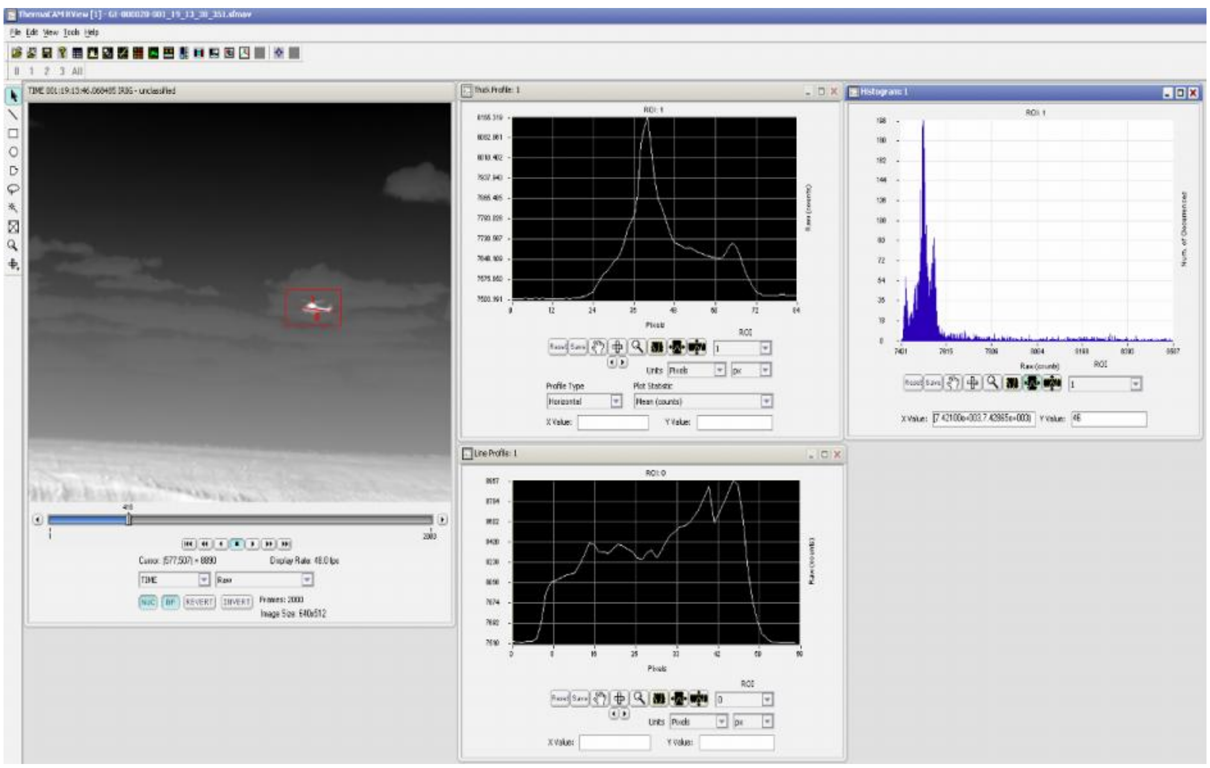

Fig.5 – Analysis of a helicopter at high altitude

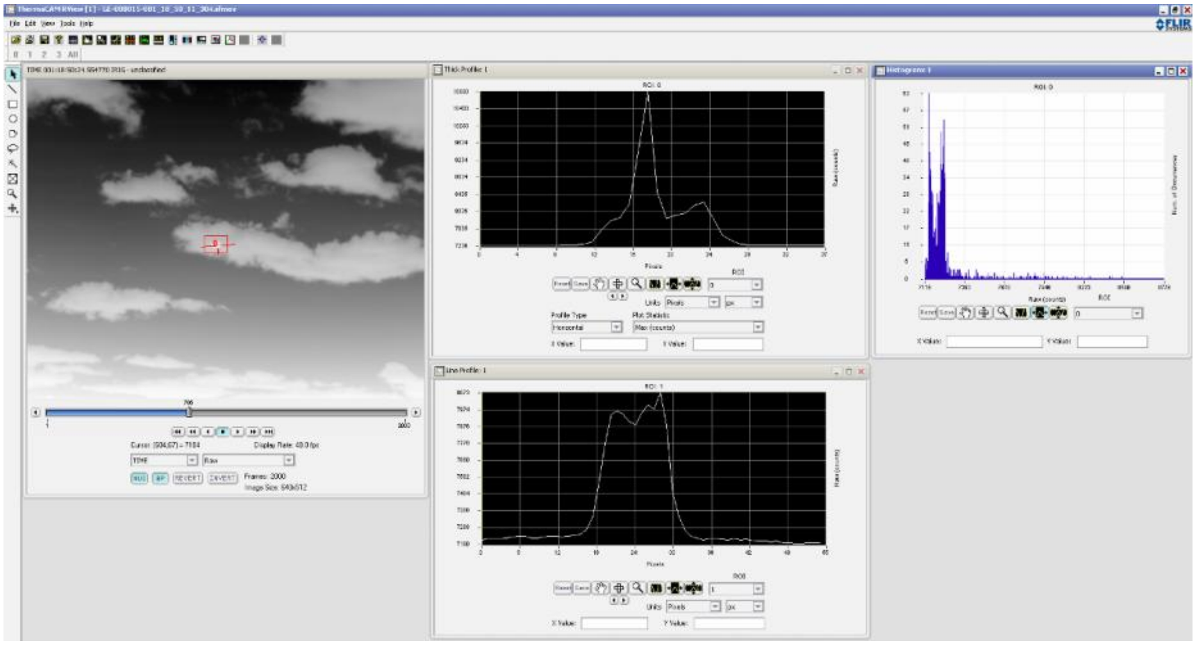

Fig.6 – Analysis of a helicopter at high altitude with cloudy background

The outcomes from the analysis allowed to identify the following issues:

- The detectability of the helicopter in look-up and, at high altitude, near horizon sensor view is mainly driven by the helicopter flight conditions due to the generally cold background radiance generated by the sky.
- The detectability of the helicopter in look-down and, at low altitude, near horizon sensor view is driven by the specific scenario condition and by the helicopter flight conditions due to the generally warmer background radiance generated by the surface.
- The cloudy sky background condition can modify these general findings due to the increase of average radiance values and increase of clutter content caused by the scattered sun radiation.

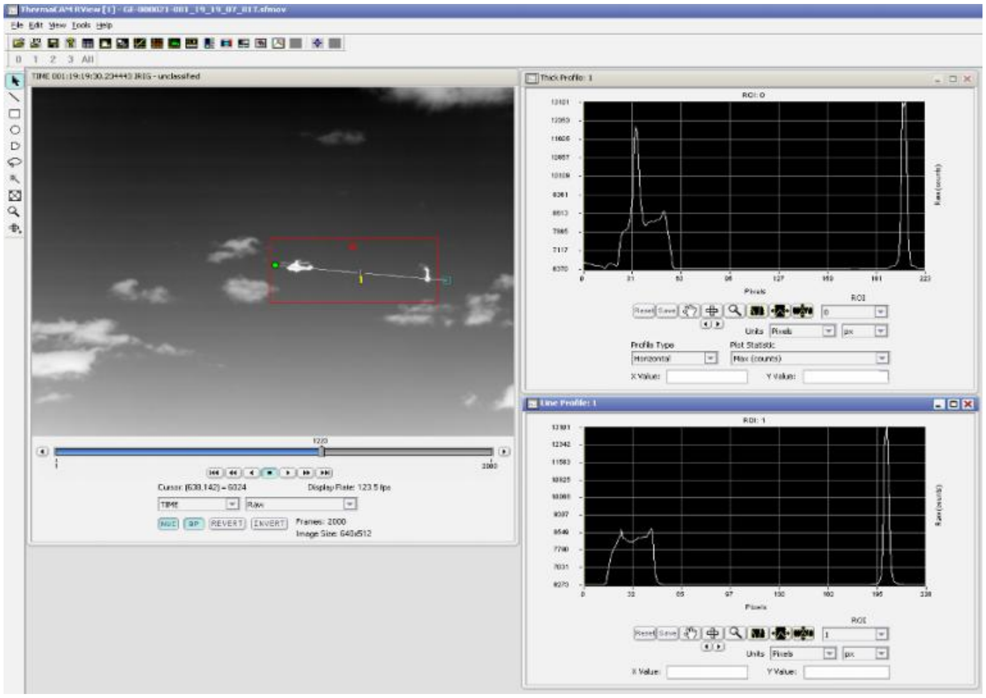

Fig.7 – Analysis of countermeasure effectiveness

In fig.7 it is analyzed the effectiveness of a countermeasure used by the helicopter. In the graphics we can see that the countermeasure temperature is higher than helicopter temperature. Also the burning time allows the pilot to take a maneuver for hit avoidance.

CONCLUSION AND RECOMMENDATIONS

The following conclusions must be considered:

- Simple techniques and innovative tactics are effective in countering the use of sophisticated sensors and precision weapons.
- The technologies and tactics used by an adversary are numerous, commercially available, and deserve constant attention.
- Adversaries are exchanging signature modification information, technologies, and tactics.
- Absolute belief in technological dominance is risky.

It is essential that NATO commanders and tacticians understand the potential threat provided by the presence of the countermeasures during conflicts. Also, those NATO precision weapons designers consider the effects of the countermeasures during operational testing.

a) REFERENCES:

1. *JACOBS, Pieter A. – Thermal infrared characterization of ground targets and backgrounds – SPIE Press, 2006*
2. *PLEȘA, C.; ŢURCANU, D.; BODOC V. – The use of infrared radiation for thermal signatures determination of ground targets – APPLIED PHYSICS – OPTICS – LASERS*, 2004
3. *ThermaCAM RTools Documentation – FLIR Systems, 2007*