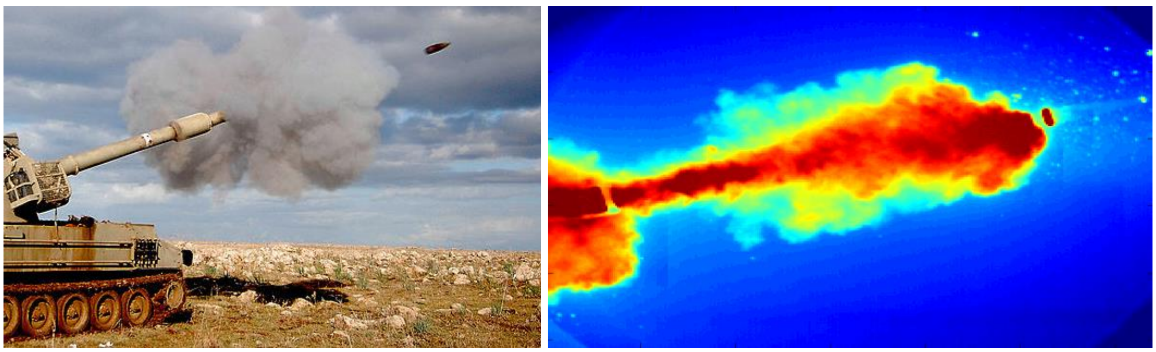
FAST Thermal Imaging – Tank/Artillery Muzzle Flash Analysis

Typical large caliber muzzle flash last less than 0.2 seconds in the MW (3µm to 5µm) band. This fact leads to the most important technological challenge when it comes to the detection and characterization of short, millisecond long events: high frame rate.

Telops was present on the test range of a military facility for the demonstration of the FAST-IR 1500 infrared camera from Telops. This application note presents the preliminary analysis of the measurements performed after the firing of ordnances from the barrel of a tank. The demonstration was developed around the application of artillery muzzle flash analysis.



(Left): Representative view of the experimental target: shell/ordnance projected from the barrel of a tank gun
(Right): Example of an actual measurement with the Telops FAST-IR 1500 cameras of shell/ordnance fired from the barrel of a tank gun.

Introduction

The demonstration was performed using the unique Telops FAST-IR 1500 infrared camera. The Telops FAST-IR 1500 is a flexible high performance cooled infrared camera. It is the fastest infrared camera in the world with unprecedented 1500 frames per second (full frame) capability. Equipped with a 320 x 256 InSb IDDCA (Integrated Detector Dewar Cooler Assembly), the detector covers the 3.0 to 4.5 µm spectral range.

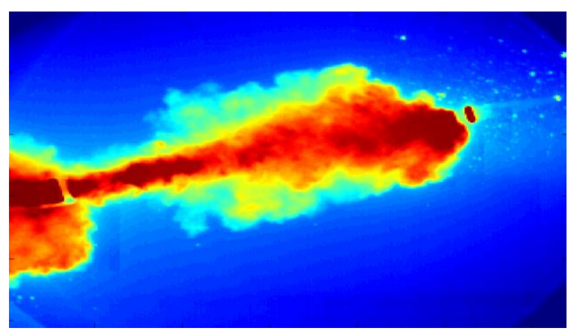


Figure 1: Total energy emitted by muzzle flash

Experimental Information

Description of a typical measurement

This section provides a quick overview of a typical scene recorded during the firing of a shell/ordnance when recorded with the Telops FAST-IR 1500 infrared camera.

Figure 1 shows the infrared image from the FAST-IR 1500 of a shell/ordnance fired from the barrel of a tank gun. The blue-color shows cold targets whereas red color shows hot targets. The end of the barrel can be seen on the left hand side as red because of its high temperature. The rear surface of the ordnance can be seen as a circular shaped surface with red color. The back shell hot temperature results from the hot expending pressurized gas pushing on the shell rear section while it is still inside the barrel. The nose of the ordnance can be seen on the right hand side of the image with bright spot, informing on the high temperature of the ordnance nose coming from air friction. Given the extremely high speed of the ordnance, its image is rendered through a slightly smeared image because of its displacement during the exposure period (Exposure time is in the order of 30 µsec).

Plume temperature gradients as well as the direction of propagation are observed over time. Some secondary debris from the ignition/blast/ejection/propagation processes can be seen as bright spots as they are at a high temperature.

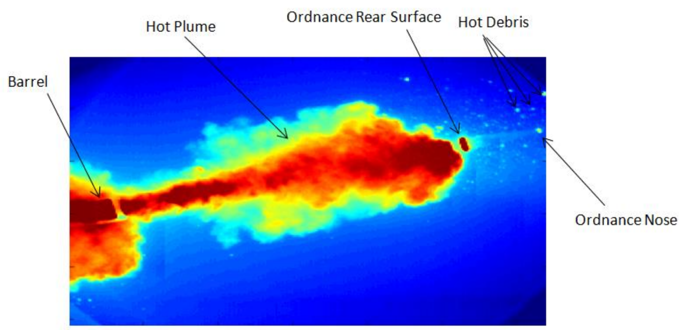


Figure 2: Total energy emitted by muzzle flash

Results and Discussion

Radiance Study

From the actual measurement of an ordnance firing, a great deal of phenomenological and quantitative information can be derived. Given the high radiometric accuracy and sensitivity of the Telops FAST-IR 1500, some key performance metrics can be evaluated from a detailed data analysis.

A typical ordnance firing duration is in the order of 170 ms. The figures below show respectively the computed total energy released (in units of Watts) as a function of time and the cumulative energy released (in units of Joules) as a function of time.

Some very interesting phenomena occur between 4 and 20 ms since this shows the blast energy (between 4 and approx 7.5 ms) vs. the flame energy (times above approx 7.5 ms). It is thus possible to separate the contributions from either the blast or from the flame energy.

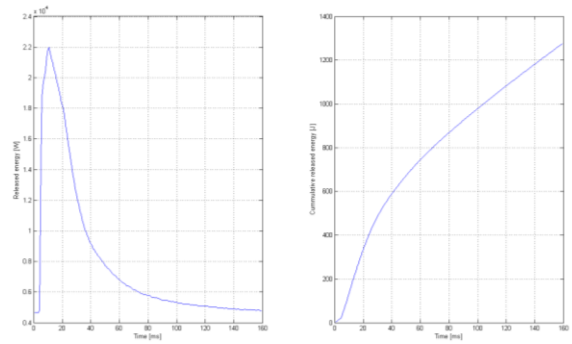


Figure 3: Total energy emitted by muzzle flash

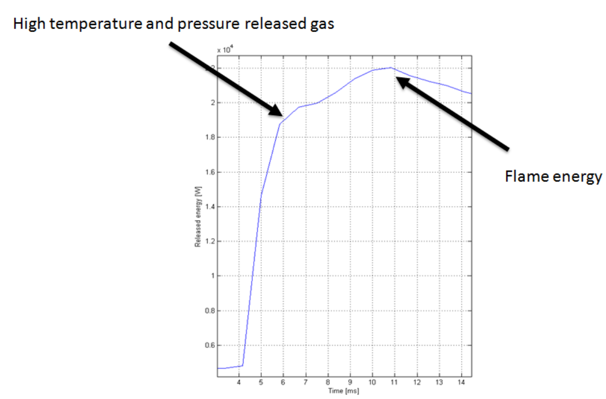


Figure 4: Total energy emitted (zoom on energy ramp-up)

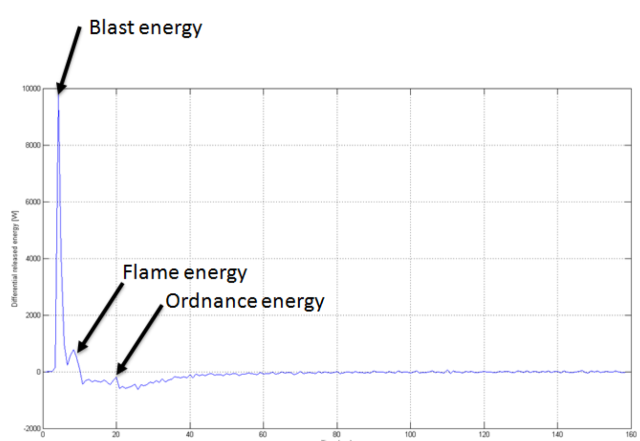


Figure 5: Differential energy study

Temperature Study

A detailed analysis specific to the determination of the targets temperatures was performed. The image below shows the infrared image of the gun/barrel before firing. The lower part of the figure shows a graph with a target radiometric temperature (assuming unity emissivity) evolution as a function of time. The temperature profile is associated with a specific user-selected pixel which is shown as a red cross on the infrared image.

As the firing of ordnance occurs, the temperature measured at the pixel delimited by the red cross changes as a function of time. From the graph, before the actual firing, the temperature is determined to be around 255K. This is the radiometric temperature measured from the sky background (sky acts as a cold source in the infrared, thus appearing as black in the image). The firing starts at about 4 ms.

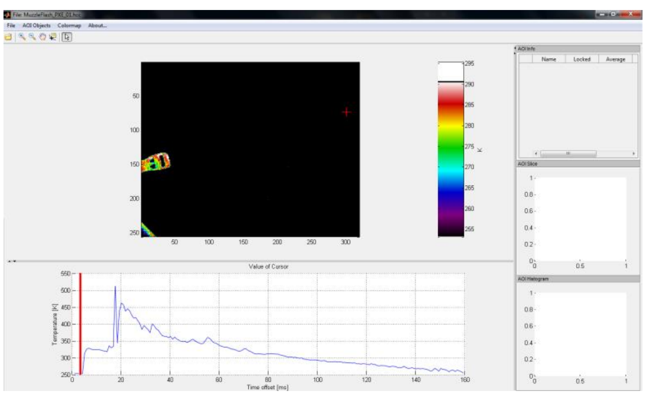


Figure 6: Temperature (red cross) before events

As the blast and ejection occur, the temperature at the red pixel position increases dramatically to about 325 K at time t = 8 ms approximately. This is seen on the next figure.

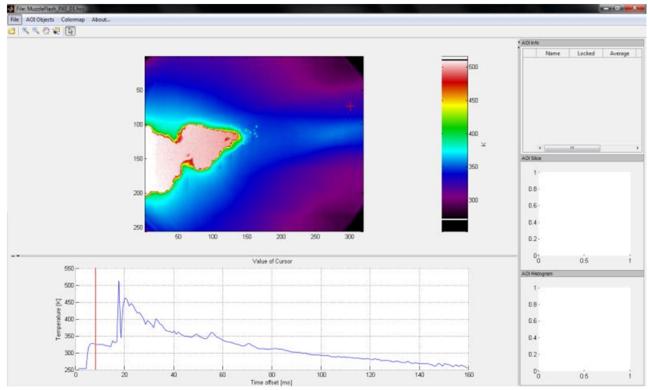


Figure 7: Blast temperature (Red cross)

As the ordnance propagates in the air, its nose temperature dramatically increases in the same fashion. The measured radiometric temperature at the position of the nose of the ordnance is 330 K.

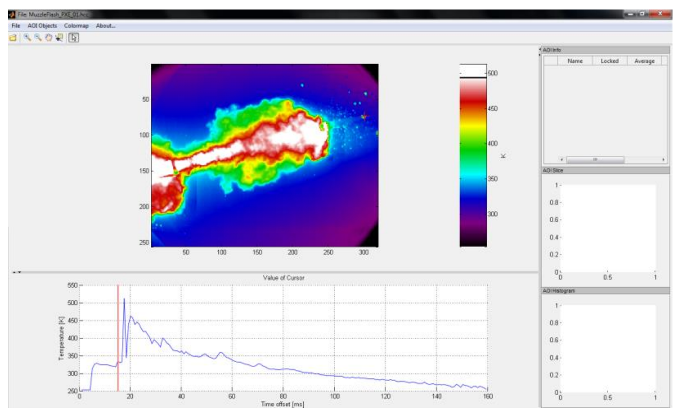


Figure 8: Projectile nose temperature (red cross)

The measured temperature at the position of the red cross then undergoes significant variations due to the passage of the ordnance and blast products as a function of time. The radiometric temperature of the rear surface of the ordnance reaches more than 400K.

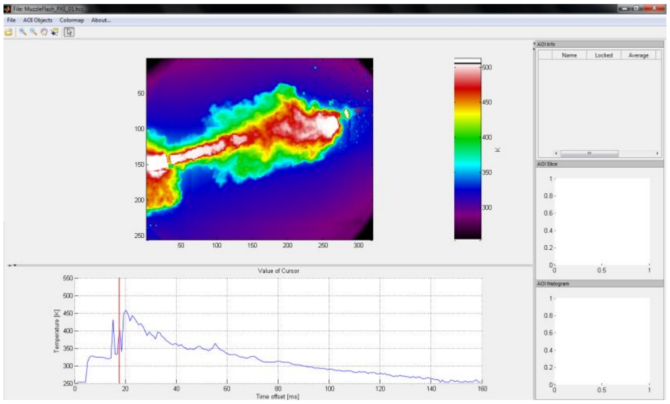


Figure 9: Projectile back temperature

The flame shows a maximum radiometric temperature of above 450 K as can be seen in the next figure.

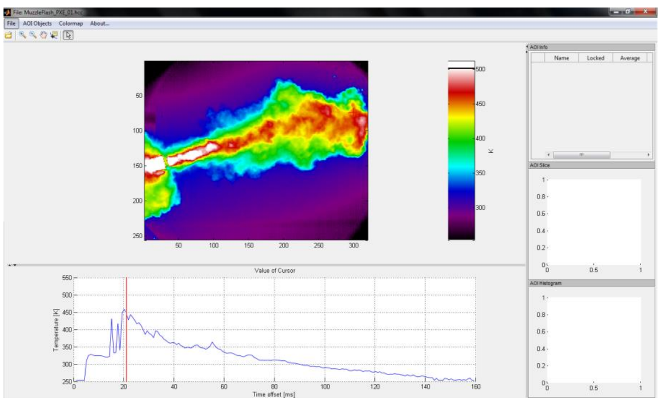


Figure 10: Flame temperature

A secondary temperature increase occurs at t = 55ms where a secondary burning is happening from the remaining powder at the rear surface of the ordnance.

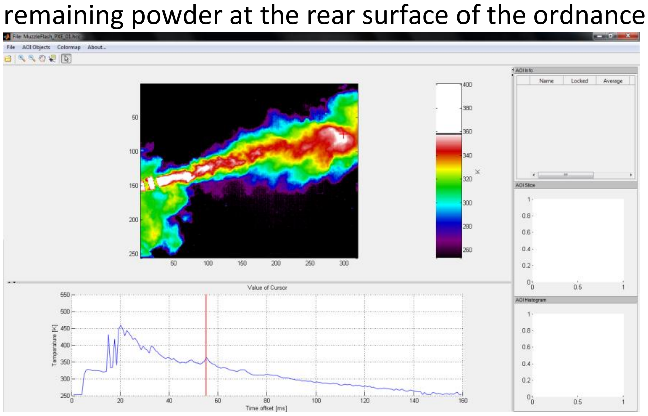


Figure 11: Secondary burning (powder remaining on bullet back)

The detailed analysis allows for the determination of transverse temperature profiles. In the example of the figure below, one finds the transverse vertical temperature profile and distribution with some associated key statistical information (median temperature, average temperature, peak temperature, etc etc etc).

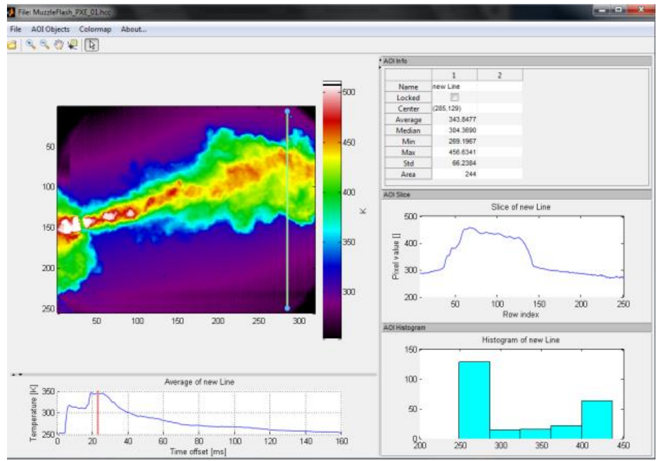


Figure 12: Temperature profile (vertical line)

Conclusion

In conclusion, by analysing the thermal characteristics observed during a typical ordnance firing with a FAST-1500 scientific infrared camera, the data obtained allows to precisely calculate the multiple energy levels emitted as well as the important thermal variations during the event. This hereby allows an in-depth analysis of tank muzzle flash performances.

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