# FAST Thermal Imaging – The New Way to Look at Explosions

**Explosions are unfortunately at risk in many working environments, jeopardizing several workers. The heat and shock waves resulting from an explosion are harmful and lead to major endangerment or casualties. More precisely, dust cloud (small particles) explosions are even more malicious since they often result from ordinary materials such as coal, flour or pollen. Also, many metal powdered (such as aluminum oxide and magnesium) can form dangerous dust cloud explosive when they are in suspensions in air. The understanding of this particular type of explosion is critical for the preventive care of sites and workers afflicted to such conditions.**

**In order to study the thermodynamic processes involved in such explosion, scientists need to understand the main characteristics of the ignition, explosion and propagation phenomenologies. The efficiency of an explosion is usually characterized by the quantity of energy that is released, by the velocity at which the thermally expanding gases are released and by the spatial and temporal evolution of the generated heat wave and released particles.**

**This application note presents the measurement results of a dust cloud metal particle explosion using high speed infrared imaging. The capability to characterize such a rapid event can be best fulfilled by the unique Telops FAST-IR 1500 high performance infrared camera.**

## Metal Particules Dust Cloud Explosion

Metal particles dust clouds are created using a mixture of different particles such as magnesium or aluminum oxides. Typical metal particles size is only a few microns in diameter. To simulate a dust cloud, metal particles are placed in small cone-type containers. (Figure 1, Left) Pressurized gas is then blown under each container to spread out the dust cloud. (Figure 1, Center). Finally, to initiate the explosion process, a hot thermal source is launched inside the dust cloud, generating a chain of explosion ignitions.

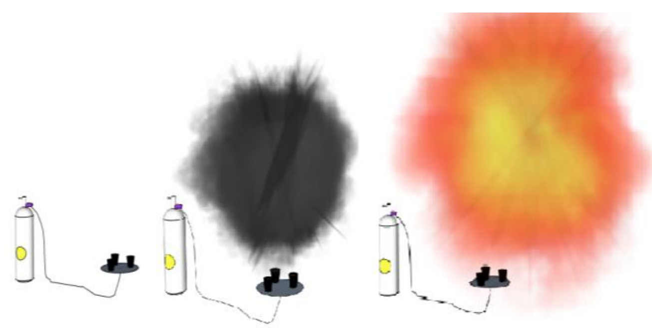


**Figure 1: Metal particules dust cloud explosion**

## Field Test Experiment

Figure 2 illustrates the experimental setup used to demonstrate the benefits of analyzing the explosion with a high speed thermal imaging camera. The Telops FAST-IR 1500 is pointing perpendicularly to the explosion at a distance of 30 meters. The experiment setup parameters are listed in table 1.

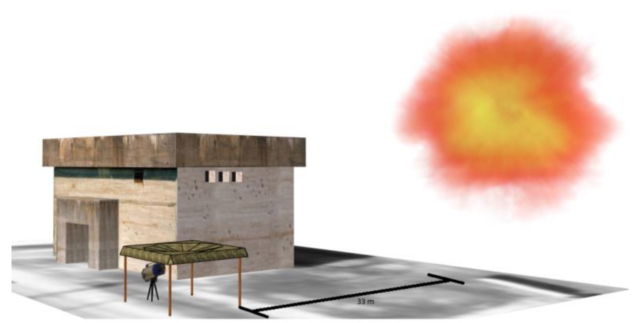


**Figure 2: Experimental setup**

**Table 1: Experimental Setup Main Parameters**

| Parameters | Unit | Value |
|---|---|---|
| **Distance to explosion center** | m | 33 |
| **Camera frame rate** | Hz | 1500 |
| **Spatial resolution** | Pixels | 320x256 |
| **Camera FOV** | ° (HxV) m | 20 x16 |
| **Camera sensitivity** | mK | < 20 |

## Results and discussion

The results reveal an unprecedented capability of measuring key explosion characteristics. Figure introduces the step by step radiance signature evolution of the explosion. The time difference between consecutive frames is 666 microseconds. While the top left image illustrates the primary ignition point, the following five images reveal interesting details on the turbulent flow created by the secondary ignition points. The detailed analysis of the last three images allows for evaluating the metal particle explosion ignition propagation and ranging effect. To better illustrate the

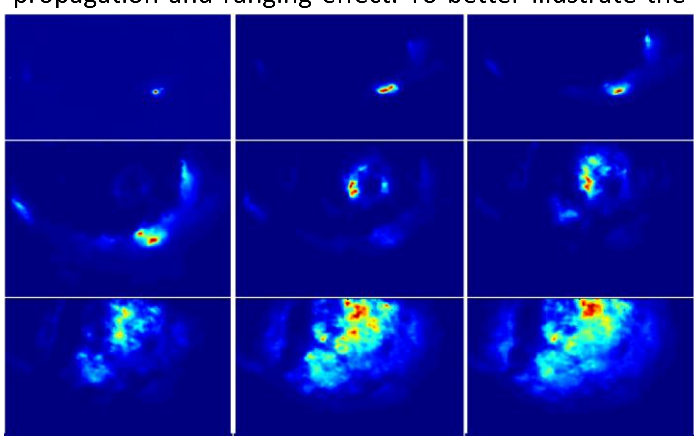


Figure 3: Step by step explosion

secondary ignition points, a radiance difference between consecutive images is calculated and presented in Figure 4. Several individual ignition points (secondary) can be detected from the local peaks (between 35ms and 45 ms). For instance, at about 38ms following to the beginning of the sequence, and roughly every 2 ms, peaks appear, indicating a difference in local radiance. These local peaks result from secondary ignition points propagating into the dust cloud. The ignition points effective range is calculated through a dynamic flow analysis based on a Telops proprietary pixel per pixel temporal radiance variation technique (patent pending). This technique is illustrated in Figure

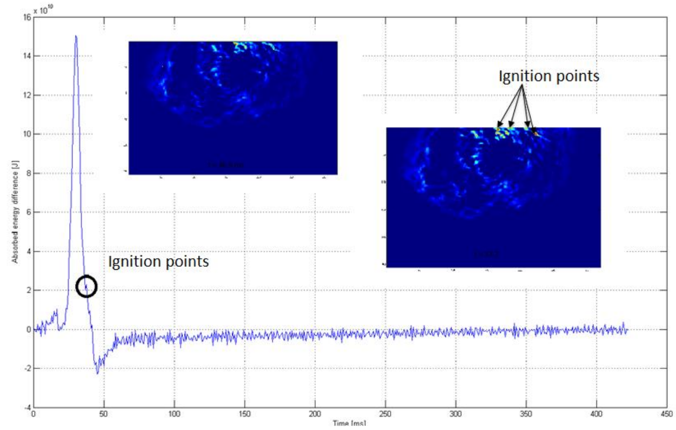
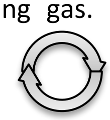
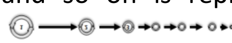



Figure 4: Explosion ignition point propagation graph

5. The small red vectors represent the flow direction, while the length of the vectors corresponds to the velocity of the expanding gas. From this map, local maximum (marked with ) reveal the ignition points. The local ignition points range is calculated from the flow speed and direction. (Interpretation: The scheme where ignition point 1generated the ignition point 2 and so on is represented by the following symbols: ).

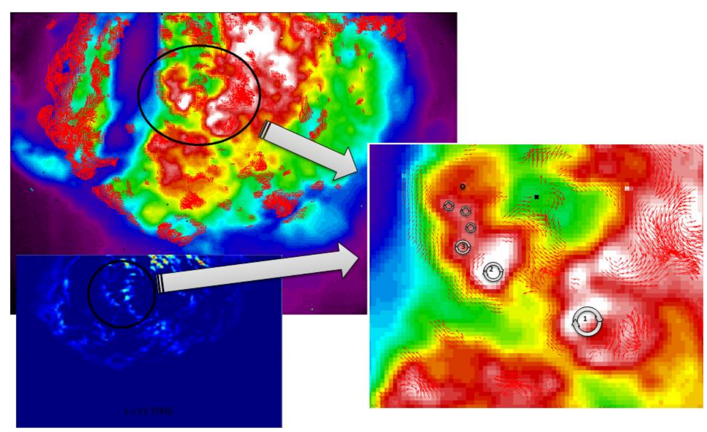


Figure 5: Flow direction and velocity analysis

High-speed infrared imaging also allows to compute the flow velocity profile resulting from an expending gas. As illustrated in Figure 6, the gas velocity surrounding the ignition point 1 is [U, V] = [3410, 5530] pixels/s, where U is the horizontal and V is the vertical velocity. From this result, local kinematics energy resulting from an isolated ignition point can be retrieved, helping to understand the local thermodynamic behavior.

The high performance FAST-IR 1500 infrared camera also allows to provide critical information such as the total generated energy over time and the active radius of the total explosion. As shown in Figure 7, one finds the total emited energy and surface temperature occuring during the explosion. In fact, the total energy peaks at about 40 MJ ( equivalent to ~ 9 kg of TNT ) after approximatively 5 to 8 ms following the primary ignition. More than 25% of the total energy is released within this time frame. The maximum measured temperature is above 2700K. Moreover, the total explosion active radius of ~8.5 meters is directly calculated from the sequence.

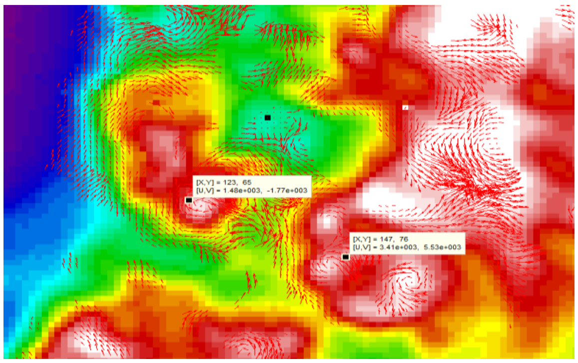


**Figure 6: Expending gases velocity and direction**

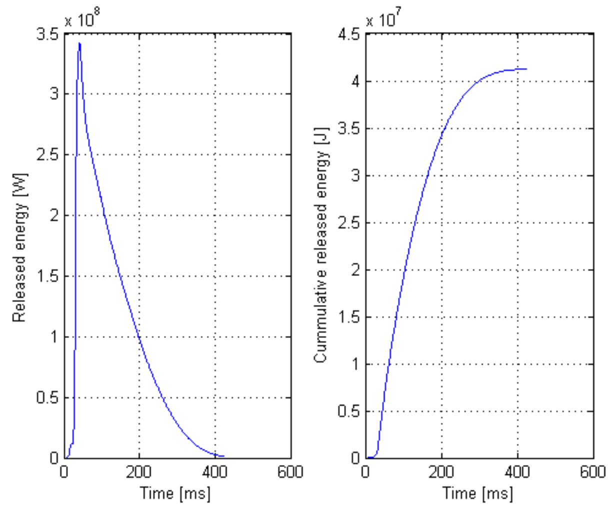



**Figure 7 : Energy released by the explosion**

## Conclusion

There are several key benefits to characterizing an explosion using high-speed infrared imagery. It allows for a direct measurement of the total energy released and of the active radius. Such data and derived information helps scientists to better understand the thermodynamics of the explosion as well as the ignition and heat/particle propagation inside the active explosion area. All these phenomena can easily be recorded by the unique Telops FAST-IR 1500 infrared camera. Its unique high frame rate makes it the perfect tool to bring the explosion analysis and research to the next level.

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