Application Note

FLIR

High Speed Infrared Imaging and the Ballistics of "Punkin Chunkin"

In an effort to improve the performance of their massive 120 foot pneumatic air cannon at the 2012 World Punkin Chunkin Championship (WCPC), American Chunker team captain Brian Labrie invited FLIR Systems' infrared experts David Bursell and Ron Lucier to join his diverse crew of chunkin'-crazed engineers, scientists, and fabricators. With the addition of a high speed, high resolution MWIR infrared camera, the team was able to use thermal analysis of pumpkin ballistics to improve design and performance as they prepared for the event.

Simply put, ballistics is the study of the flight, behavior, and effects of projectiles as well as the science or art of designing and accelerating projectiles to achieve a desired performance. So, when you think about it, the science of launching a pumpkin out of an oversized air cannon just to see how far it can go is a prime candidate for ballistic study.

By definition, a ballistic body moves and behaves freely, with changes in appearance, contour, or texture triggered by ambient conditions, substances, or forces, i.e., the pressure of gases in a gun, rifling in a barrel, by gravity, by temperature, or by air particles. In this case, the ballistic body in question just happens to be a large vegetable propelled out of cannon by the force of released compressed air.

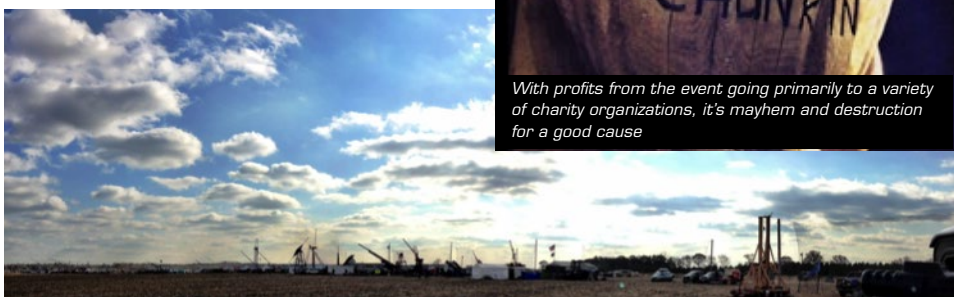
Background

The World Punkin Chunkin Championship has taken place annually just after Halloween in Sussex County, Delaware for over 25 years. Over a hundred teams compete in a number of divisions with the air cannon contingent capable of hurling the pumpkin by far the longest distances, over 4,000 feet for elite competitors, including the American Chunker team.

If a giant cannon isn't your thing, you can also take in a variety of other wicked hurling devices including catapults, torsion-powered machines, trebuchets that operate with counterweights, and for back-to-basics types, even the simple force of brute human strength. With the addition of female and youth divisions, the contest is well on its way to becoming an established sport—and a popular televised holiday spectacle as well.

The Science Channel owns broadcast rights to the event, airing the contest itself on tape delay on Thanksgiving Day. "Road to the Chunk" special segments are shown earlier to pique viewer interest before the big day. The Discovery Channel's Mythbusters program has also presented coverage of the event for the last three years to stellar ratings

With profits from the event going primarily to a variety of charity organizations, it's mayhem and destruction for a good cause

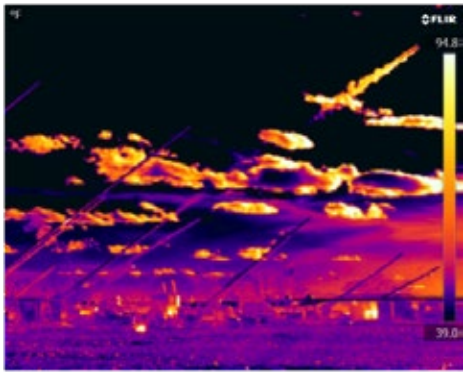


Panorama of pumpkin-hurling gadgets at the 2012 Chunk

How the Contest Works

Each division competes strictly for distance except for the theatrical division which relies on a fan vote. The teams get three shots, one taken on each of three consecutive days. Only the teams' farthest shot is scored for official results. Pumpkins (by rule between 8-10 pounds and usually thick-walled, robust varieties) must remain whole after leaving the device for the chunk to count. Pumpkins that burst after leaving the barrel or sling are "pie" (short for "pumpkin pie in the sky").

Spotters riding on ATVs find the impact point, and then a professional surveyor calculates the distance based on GPS coordinates of the impact and the machine. The impact point is marked with color-coded spray paint to avoid confusion with future shots. Safety is a number one priority with only fatality thus far being an unfortunate duck felled by an air cannon-launched pumpkin.

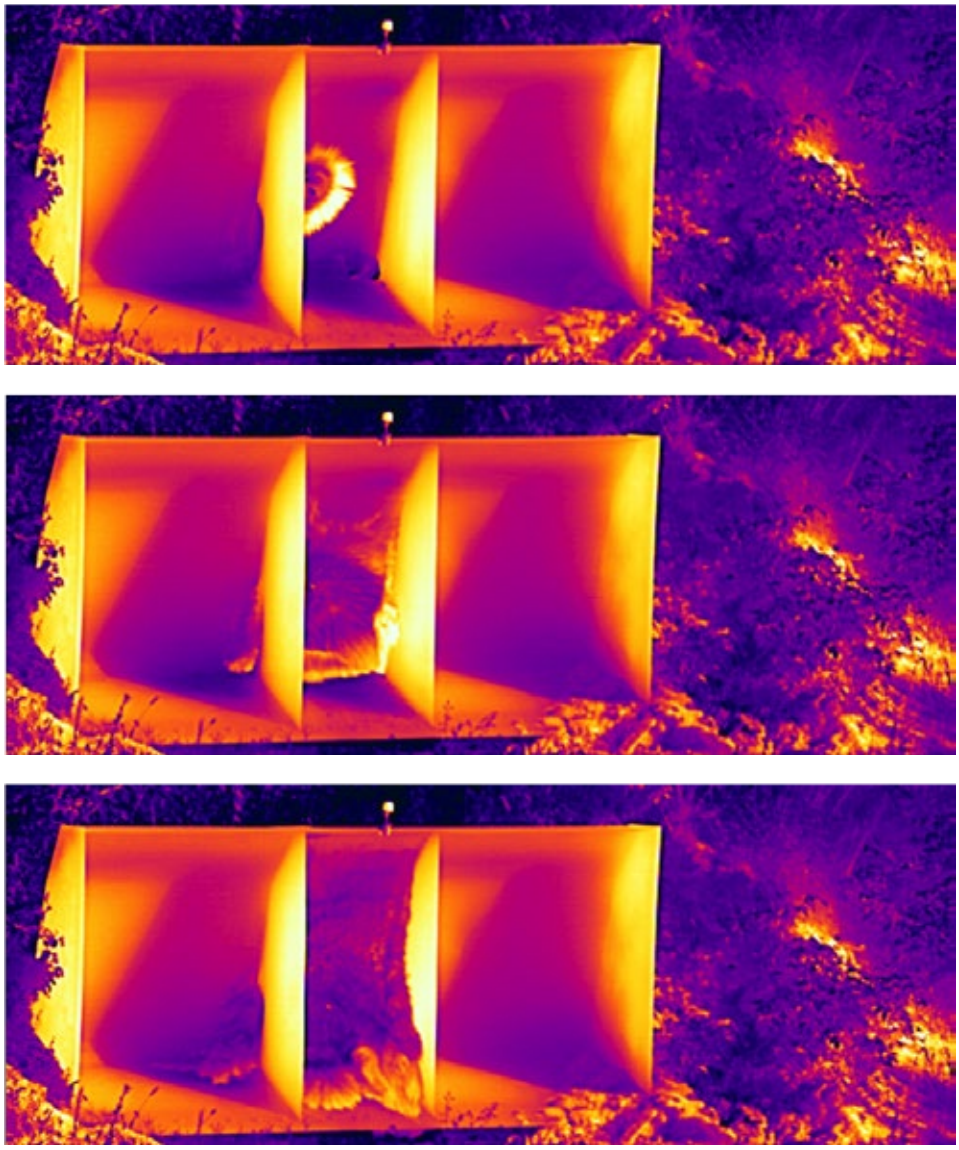


This thermal in the iron palette shows a pumpkin pieing" in midflight—the area in the circle is not a cloud, but a trail of exploding pumpkin matter.

Pumpkin Ballistics

As with any other air-powered projectile, just how far Team AC's pumpkin can fly rests upon a number of variables which lend themselves to thermal analysis.

- Are air leaks or moisture collecting inside the cannon a factor?
- Exactly how does the pressurized air strike the pumpkin?
- What is the speed of that air that propels the pumpkin down the barrel?
- What is the barrel temperature?
- How much and in what manner does barrel friction affect the pumpkin's speed?
- What is the impact of humidity and wind speed on the pumpkin's trajectory after it exits the barrel?
- What is the pumpkin's velocity?
- What can the spin or rotation tell us?
- What happens to the pumpkin as it strikes the target?



These 3 images are part of a 10 shot stop motion sequence that show in very clear infrared detail exactly what happens to the pumpkin as it reaches its final destination, a large chambered bucket, and distintegrates

The Next Victim

The SC6800 on the job at Chunk 2012.

The SC6800's highly sensitive cooled indium antimonide (InSb) sensor detects even subtle thermal differences and on-board ambient drift compensation guarantees +/- 1% or 1 degree temperature measurement accuracy of high speed targets or highly dynamic thermal events in various thermal environments.

Calibration Allows Quantitative Analysis

In addition, the camera can be both thermographically- and radiometrically-calibrated—meaning that it not only yields fantastic imagery, but extremely high quality data for quantitative analysis. The 50-500 continuous zoom lens ensures that even from necessary safety distances, no detail is lost. Full frame, full speed calibrated imagery and data are output easily to a data recorder for further analysis via simultaneous gigabit Ethernet, Camera Link, CoaxPress(CXP), or HD-SDI options.

Why Use Infrared?

High-speed IR thermography can reveal hidden features of fast-moving objects when their temperature is higher than the background. It takes a special kind of camera to get this kind of data and the infrared contingent on Team AC was able to provide it via the FLIR SC6800.

Windowing Permits Stop Motion Imagery

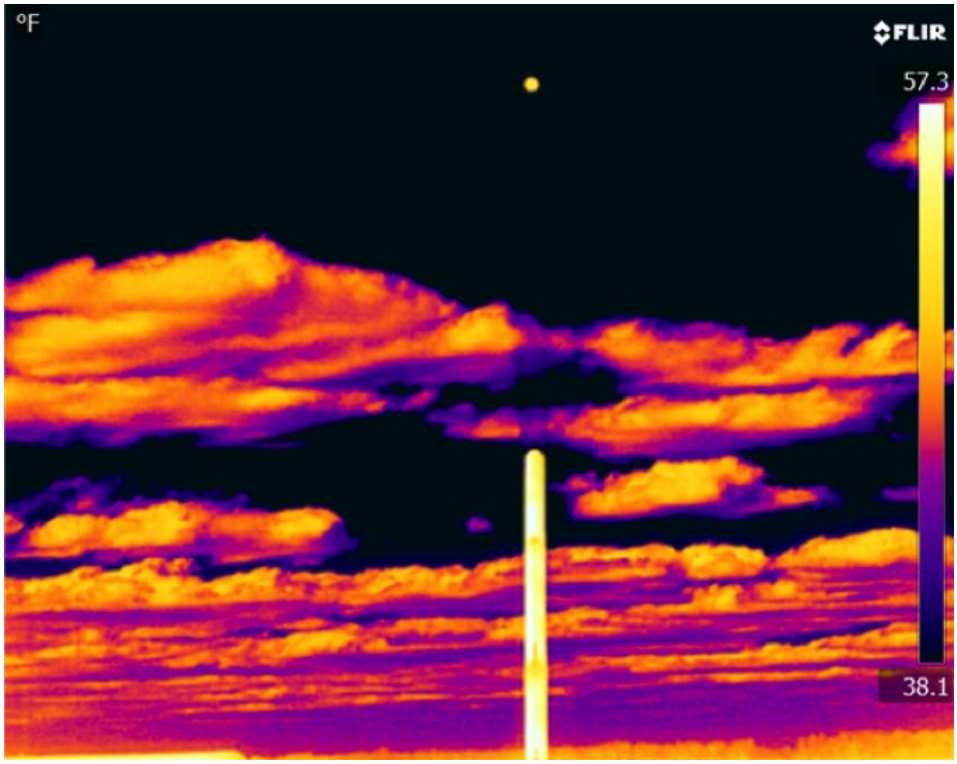
In order to capture the pumpkin's flight, fast frame rates were essential and this camera offers 565 frames per second at full 640 x 512 resolution. Windowing or sampling of frames permits the capture of thermal images at rates exceeding 10,000 frames per second. This is equivalent to an exposure time of a few microseconds. Thus, individual video frames can provide still images of a fast-moving target or thermal event, referred to as stop-motion imaging.

Slow Motion Video Made Possible by Fast Integration Times

Whether a stop-motion image or a video sequence, high-speed IR cameras can supply images of fast-moving objects with minimal blur. FLIR's advanced camera systems make this possible with analog-to-digital (A/D) converters that provide high resolution and short integration times. The shorter the integration time, the less likely there will be blurring. When data acquisition is fast enough, it's possible to capture a sequence and play it back in slow motion. Check out the video featuring both thermal and visible imagery of the 2012 Chunk on the FLIR website.

High Sensitivity and Accuracy Avoid Blurring

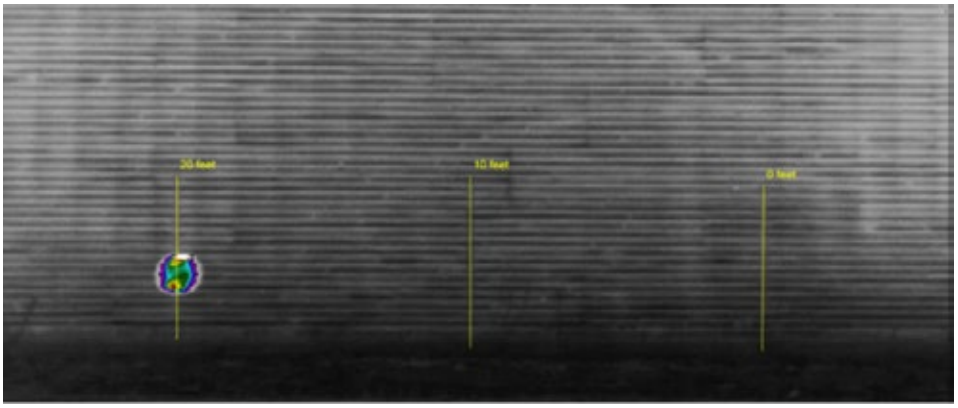
Avoiding image blur is also tied to the superior thermal sensitivity of FLIR camera detectors. With highly sensitive detectors, the data integration time can be shorter, because less energy (IR radiation) is required to record an acceptable image. This is particularly important when you need to see fast-moving, low-energy targets like a pumpkin on a cool day, or against a cool sky.



Stop motion IR image in iron palette of pumpkin in flight

The Results

At Chunk 2012, Team AC, only four years old, took home third place with a shot of 3,788.04 feet, just 93 feet out of first place. For 2013, the American Chunkers have set goals to break the current world record (4,483 feet) and achieve a major tournament win. Improvements have already enabled Team AC to chunk a pumpkin faster than the speed of sound.



Thermal imaging was used to check the validity of the speed gun mounted at the end of the cannon. Lines were drawn every 10 feet on a building that the pumpkin passed by. By measuring how quickly the pumpkin reached these points, speed could be very accurately measured.

This image shows the vapor/exhaust exiting the rear of the cannon after the shot. The triangular dark area within the triangle is not a cold area on the building, but actually supersonic airflow—this pumpkin actually broke the sound barrier (343.2 meters per second, roughly 768 miles per hour) complete with sonic boom. Without IR imaging, it is impossible to even see the pumpkin leave the cannon with the naked eye, it's moving so rapidly.

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