Optimizing Workflow For High-Speed Imaging Applications

By Toni Lucatorto and Frank Mazella, Vision Research

Today's advanced high-speed cameras are used to record phenomena that are otherwise not visible to the naked eye by capturing the details of fast-moving events. While the images can be incredible, the high frame rates and pixel resolutions used can generate extreme amounts of data in a short period of time. This makes it imperative to optimize the high-speed imaging workflow for the application at hand.

Best practices for downloading images from the camera's RAM depend on the available time between each shot and whether the camera is linked to a computer, used in a stand-alone configuration, or part of a multi-camera setup. Whether imaging in a laboratory, outdoors, or on a movie set, planning an efficient workflow is vital to achieving the best results.

CREATING AN EFFICIENT LABORATORY WORKFLOW

High-speed cameras help scientists make new discoveries every day. In the laboratory, the camera is typically "tethered" via Ethernet to a computer used to control the camera. After the camera acquires and stores the images, the raw files can be saved directly to the tethered computer's hard drive. The camera's software can save and recall the settings used for a specific experiment and make basic measurements immediately. After analysis is finished, the files are often archived in a compressed file format such as AVI or QuickTime, which can also be used for presentations and publications.

High-speed cameras were key for a laboratory study of drop-particle collisions, which involved capturing the interactions of a particle with a drop of liquid in mid-air.[1] For this study, researchers used high-speed cameras at 4,000 frames per second (fps) to capture both the front and side view of the water forming around beads and various materials. The information gained from particle wettability studies is crucial to a variety of fields, such as tablet coating within the pharmaceutical industry and certain kinds of heavy crude oil refinement. https://youtu.be/fGtwid4QZN8

How much data gets generated in 1 second at 1,000 fps?

Camera Resolution (12-bit)	Recorded Duration	Size of Data (Gigabytes)
1 Megapixel	1 Second	1.5
4 Megapixels	1 Second	6
9 Megapixels	1 Second	13

FILE TYPE MATTERS

A high-speed camera's sensor records raw data, with image processing applied as metadata. The raw files can be considered the camera's digital negative.

For scientific and industrial applications, it is important to use images in this raw format for measurements to ensure the integrity of the data. For the cinema industry, the raw format is preferred for editing because it provides the highest-quality images.

Converting raw files to interpolated or compressed formats has advantages too. The files can become much more manageable in size, depending upon the file type and algorithm, and compatibility with common video players and editing programs is guaranteed.

Optimizing Workflow For High-Speed Imaging Applications

For applications such as ballistic studies, high-speed cameras can capture the moment a projectile impacts an object or material and how it rotates while traveling through the air. Because bullets can be shot repeatedly in fast succession, measurements aren't performed until after all images are acquired. This makes it useful to choose a camera with larger RAM, which can then be partitioned. Multiple shots can be taken in succession and then offloaded for later analysis.

CAPTURING FLEETING OUTDOOR EVENTS

High-speed cameras are often used outdoors in tethered configurations. In this environment, the shot is typically acquired and stored in the camera before being quickly offloaded to secure, removable media.

Different types of storage media are available for quickly offloading data from the camera's RAM, though high-speed camera models are usually designed to operate with a specific type of media. Media types range from proprietary designs to maximize the speed of data transfer with a specific high-speed camera to standard commercial solutions incorporated into a camera's workflow. The commercial solutions are generally less expensive, but typically do not transfer data as quickly as proprietary solutions.

Outdoor phenomena such as lightning can be challenging to capture because it is impossible to predict the timing of a lightning strike or how many strikes might come in quick succession. An optimized workflow made it possible for researchers to capture lightning connecting to lightning rods on the top of two buildings.[2]

The researchers used high-speed cameras at 40,000 fps and 7,000 fps to capture the extremely fast phenomena of lightning hitting lightning rods. In just seconds, they downloaded the footage from the camera's RAM onto removable media and were ready to capture the next strike. Using their captured

DIAGRAM OF A SIMPLE LAB SETUP

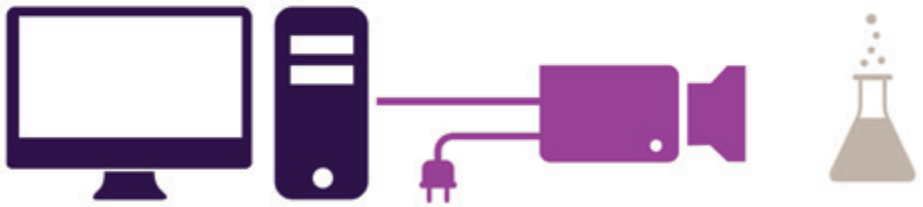
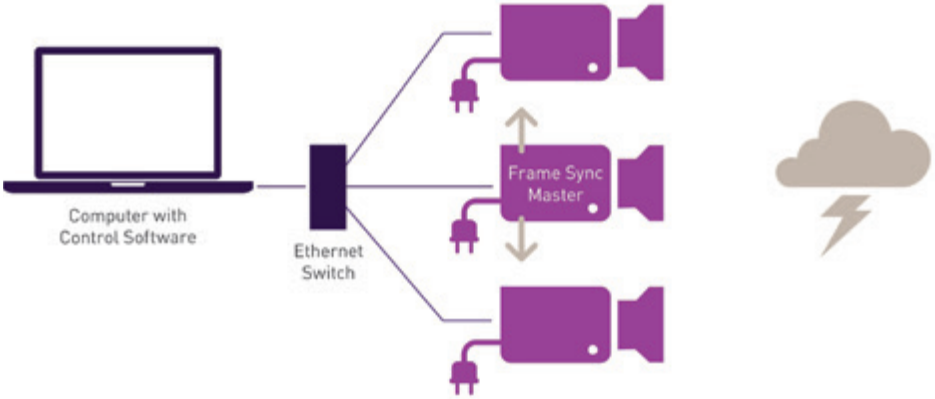


DIAGRAM OF MULTI-CAMERA TETHERED SETUP



WORK FASTER WITH 10Gb-E

Tethered setups, whether in a laboratory or outdoors, can benefit from using 10Gb Ethernet for transferring files. This type of Ethernet connection moves the raw data out of the camera RAM at rates up to 10 times faster than traditional Ethernet connections.

The time savings can be significant. For example, a 5-second, 4K clip at 1,000 fps will be about 60 GB. This file will take about 20 minutes to save with a good computer; however, with a 10Gb-E connection this same file will save in under 2 minutes.

This time savings is crucial to the cinematography industry, where data is offloaded from large, portable media drives that hold terabytes of data.

To maximize the transfer speed of 10Gb Ethernet, remember to:

- Use a PC that is recommended for 10Gb-E networking. For laptops, this will involve a Thunderbolt connection and the use of a 10Gbase-T Ethernet to Thunderbolt converter.
- Save the files to a solid-state hard drive, ideally a SSD RAID. This will provide the fastest sustained write speed.
- Dedicate the computer to be used only for high-speed acquisition and download.

footage, the researchers calculated the striking distance and speed of the discharge flowing down from the storm cloud and up from the lightning rod. This information could be used to better understand how lightning rods work and to make them safer.

If the subject is repetitive and requires very short downtime between shots, it is possible to partition the camera's RAM and use a continuous recording function. With this, the camera will automatically save each shot after it is triggered and then re-arm itself to be ready for the next shot right away. With continuous recording, the only limitation to the number of shots that can be acquired is the space available on the hard drive. When using these features, it is important to know the event's duration to ensure the entire event is saved.

Many outdoor setups involve several networked cameras that are controlled by one computer. With multi-camera setups, the cameras are all synchronized to one master source. This can either be one of the cameras, or it can be a time code source. Sometimes frame delays are introduced to ensure that one of the cameras will capture an extremely quick event, such as crack propagation in glass and other solid materials. Delays can also be used for events lasting longer than one camera can record. In this case, each camera is set to record at various intervals after the first camera, so the overall duration of recording is long enough to capture the event.

Untethered setups are often used in outdoor applications such as scientific field work, inspections of a chemical plant or pipeline, recording wildlife, and extreme sports. Battery power, on-camera controls with a viewfinder or video monitor, and removable media are imperative for these applications. For events with repeatable durations, using the camera's autosave function will automatically save the data — edited to a specific range or saved in full — to removable media after the RAM buffer fills. This function is also ideal for repetitive tests where the information is too important to lose, because multiple shots can be saved to portable media, protecting it from loss in the event of a power outage.

DIAGRAM OF A SIMPLE STUDIO SETUP

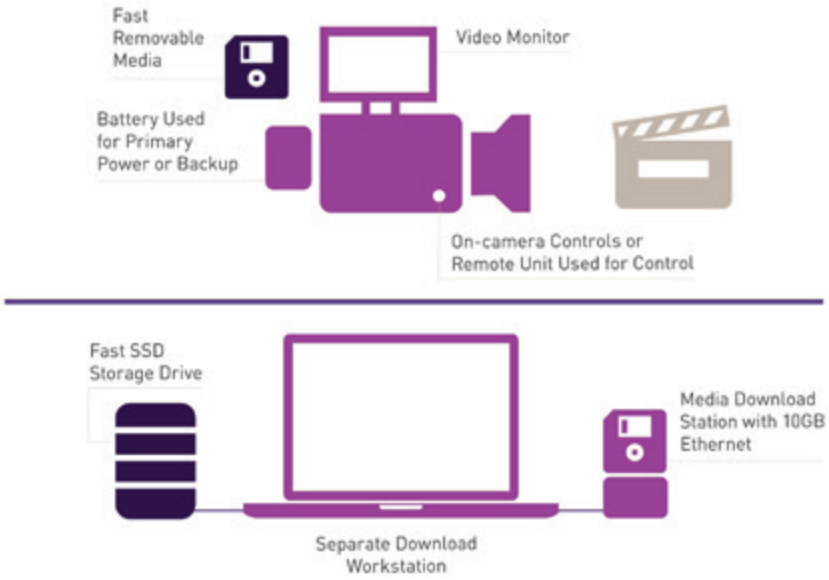


DIAGRAM OF UNTETHERED SETUP

REDUCING DOWNTIME ON THE MOVIE SET

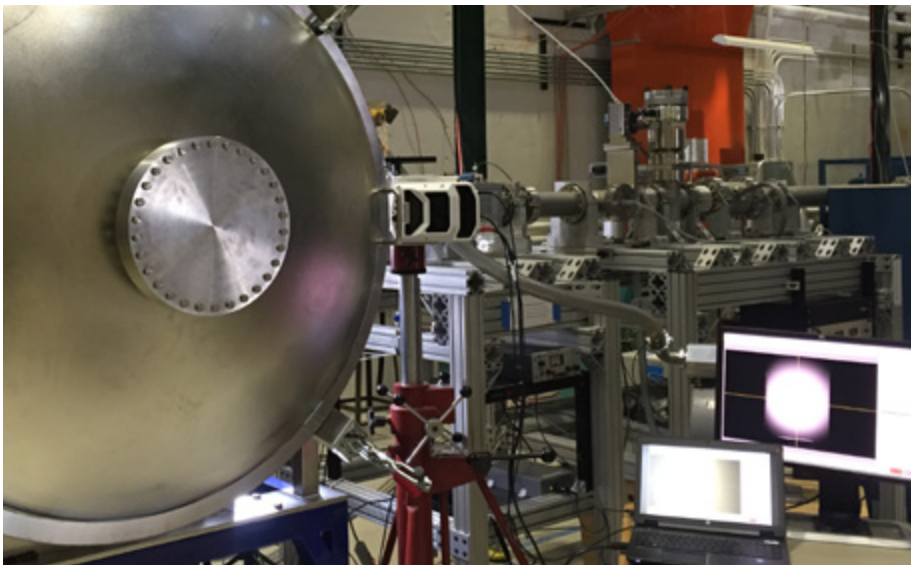
Although still considered specialty cameras in the media industry, high-speed cameras are used for everything from commercials to shooting practical effects for feature films. Because high-speed cameras shoot at up to 30 times the speed of typical cinematography

cameras, they are often used to capture detailed, dramatic movements in fight scenes and explosions.

In this setting, the camera is typically operated with on-camera controls or with a dedicated remote-control unit, with multiple video monitors and viewfinders used to compose the shot and monitor focus and exposure. After shots in RAM are reviewed, they are transferred to fast, secure, solid-state portable media drives that can hold up to 2 terabytes of raw data.

Downtime on the movie set can add significant costs to budgets that may already be in the millions of dollars. For this reason, the key criteria of the high-speed camera is its ability to support a very fast on-camera workflow, where the camera is operated without a computer and file download happens separately with a dedicated download station. Ultimately, this workflow saves the production time and money, which is critical in an industry that relies heavily on rentals and a strict schedule.

When a portable media drive is full, the download station is used to save the data to a secure location. Using a fast 10Gb Ethernet connection is key when downloading media drives that hold terabytes of data. A copy of the raw file is saved to two drives to provide an archive and insurance. Although the raw files are ultimately used for color grading and the initial edit, a compressed version of each day's shots is saved for the director to review the day's footage.



A v2511 in a "simple lab setup" to study high-speed micro-electrical sparks.

High-speed cameras that support fast, removable media often include a direct-record mode that bypasses the RAM of the camera. This limits frame rates to around 120 fps but allows much longer recording times, making the "specialty" camera operate like a regular video camera. Making use of direct-record mode allows one camera to be used for effects as well as normal shooting, which is useful for projects that require one camera to capture all the footage.

References

1. Vision Research Case Study: "Outcomes of Mid-air Collisions Between Drops and Solid Particles," https://www.phantomhighspeed.com/Solutions/Case-Studies/outcomes-of-mid-air-collisions-between-drops-and-solid-particles

2. Vision Research Case Study: "When Lightning And Lightning Rods Connect," https://www.phantomhighspeed.com/Solutions/Case-Studies/when-lightning-and-lightning-rods-connect

Cover image from the making of 'Dance of the Honey Bee' by Peter Nelson using a Miro LC.

VISION RESEARCH

AMETEK®
MATERIALS ANALYSIS DIVISION

PHANTOM

ABOUT VISION RESEARCH

Vision Research designs and manufactures digital high-speed cameras that are used in a variety of professional industries and applications. Vision Research is a business unit of the Materials Analysis Division of AMETEK Inc.

Certain Phantom cameras from AMETEK Vision Research are held to export licensing standards. For more information please go to: www.phantomhighspeed.com/export