



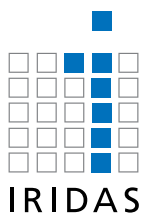
Direct-to-disk video recording using the Wafian HR-F1 was integral to Mi Casa Multimedia's documentary on tall ships of the 18<sup>th</sup> century.



Solution Brief  
Visual Computing

# Rethinking the Digital Workflow: Maximizing Image Fidelity from Capture through Finishing

CINEFORM



Parallel processing, as enabled by Intel® Core™ microarchitecture, has broken down barriers in many application areas, giving developers a means to enable concurrent processing when data-intensive operations are performed. Multi-threading allows multiple tasks to be carried out simultaneously or complex tasks to be broken into smaller tasks and performed in parallel. High-end applications in scientific research, climate modeling, 3-D rendering environments, artificial intelligence, medical diagnostics, and similar endeavors have benefited from the performance gains achieved through parallel processing.

One of the most data-intensive processing challenges is the capture, storage, and processing of high-resolution, digital-image sequences. Here, too, multi-threading demonstrates a remarkable capability for overcoming past-generation obstacles to unlock new technological possibilities. The solution described in this brief represents a fresh and radical way to handle digital cinema and video workflows, which eliminates tape storage and preserves image fidelity through the use of advanced compression algorithms. This approach incorporates the engineering innovation and design expertise of four individual companies. Each contributed to the solutions described herein—components that together provide a new model for digital filmmaking and broadcast workflows.

## The Digital Workflow Transformed

Digital workflows involve a massive amount of image processing. The sheer magnitude of the data involved has until recently handicapped efforts to bring digital image quality up to the level of film. The cameras, video storage systems, effects processors, and other components in the production and post-production workflow have been physically and technologically limited by the processing and storage requirements of the image data content. To contend with these data volumes, compression algorithms have often been applied upon acquisition, such as the DCT compression that the Sony Digital Betacam\* format employs. Because these files have normally been recorded to tape, a subsequent recapture of the material for use in a digital post-production workflow is required.

A number of issues compromise this approach. Historically, most compression applied in camera or tape formats is not suitable for use in post production; camera acquisition formats must be converted to a different format—one suitable for post-production. Otherwise, visual fidelity is compromised. Also, there are no compression standards or common compression workflows for spatial resolutions above HD, such as the emerging 2K and 4K images from high-resolution digital cameras and film scanners. Without established workflows, professionals who have needed to work in higher-resolution formats have been forced to use uncompressed files with their inherent limitations in terms of capture, storage, and processing technologies.

Consider the scope of the problem: a full-size uncompressed video capture of a 2K frame (2048 x 1556 at 10-bit quality from a film scanner, for instance) requires 12 MB of disk storage. Multiply this by 24 frames per second, and the sustained data rate demands nearly 300 megabytes per second (MBps) of data throughput, or 1 Terabyte of storage per hour. This is significantly more data intensive than even traditional uncompressed HD images, which have a throughput of approximately 125 MBps.

When we consider the emerging 4K spatial resolutions (4K images are 4x the size of 2K images), the current industry trend, uncompressed workflows become almost unmanageable. Clearly, compression must become an essential part of the workflow. This compression, however, must be intelligently applied to achieve the highest quality images upon acquisition while maintaining the high source fidelity throughout a compressed post-production workflow.

An important element in the emerging workflow for the partners in this study relates to extremely high visual-quality compression developed by CineForm. The CineForm Intermediate\* and CineForm RAW\* compression formats offer direct-to-disk camera acquisition in a compression format that is immediately usable throughout post-production workflows without any loss of source fidelity. As a result, the mammoth flow of data that uncompressed 2K or 4K frame sizes would otherwise require can be reduced to a more manageable volume for capture, storage, and processing. As part of this compression technology, metadata describing the original digital video signal is recorded so that image processing throughout post production can be referenced to a core set of baseline values. This helps enhance the full range of post-production tasks: color correction, white balance, film finishing, and effects processing.

Going directly to hard disk storage eliminates the limitations of videotape recording and the disruptions of swapping cartridges, as well as gives filmmakers a much more continuous, fluid process for capturing long sessions of live action.

## The Players

As with many of the most noteworthy advances in high-technology pursuits, the solution described in this document depends on a number of individual contributions. The four players are CineForm, IRIDAS, Silicon Imaging, and Wafian. The CineForm RAW storage format uses a visually lossless Wavelet compression algorithm to capture video information directly from the camera's digital sensor, plus associated metadata, setting the stage for optimal post-production conditions. For television production units and digital cinema filmmakers, this represents a substantial boost, both in the quality and resolution of the digital video images and in the ease with which effects, such as color correction, can be applied to the data or video stream.

Technology enhancements in camera design from Silicon Imaging also make it possible to completely rethink the video capture process. By capturing video content directly, encoding it at the camera to CineForm RAW format, and then storing it to a low-cost hard disk, high-resolution content can be recorded for many hours at a time. No tape cartridges need to be swapped. Capture can be continuous and seamless. Content remains pristine and malleable because it is recorded directly from the camera sensors. Camera settings and creative-look information are all recorded non-destructively as metadata.

The recording technology developed by Wafian works seamlessly with this workflow in shooting environments where multiple cameras are used, providing portable, on-site hard disk capture at high-resolution settings. For example, the Wafian HR-2\* recorder supports settings up to 10-bit 4:4:4 (much higher quality than HDV). And, on both the production and post-production side of the workflow, the IRIDAS SpeedGrade\* applications provide real-time color correction and film-finishing capabilities for both 2-D and 3-D content.

Let's take a closer look at the contributions of each of these players.

## CineForm

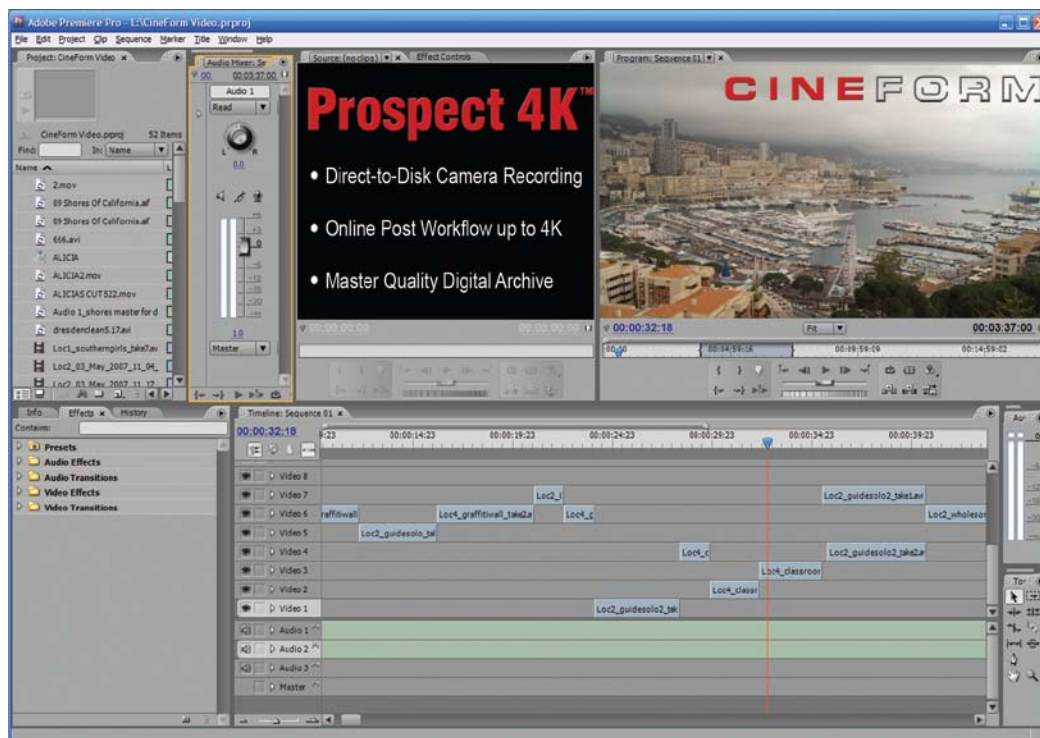
The requisite volumes of data generated during digital video recording at 2K and 4K frame sizes presupposes some form of compression as part of the process. Up to this point, the central question has been: what level of compression is acceptable without causing loss that seriously degrades the integrity and quality of the images?

Engineering staff members at CineForm looked at the challenge from a fresh perspective: what level of compression can be achieved without producing any discernable loss in the integrity and visual quality of the image from camera acquisition all the way to the end of the post-production process? By framing the problem in this manner, CineForm developed a form of compression using a full-frame temporal Wavelet transform that eliminates the block artifacts that characterize DCT compression. The nature of this codec, referred to by CineForm as Visually Perfect\*, ensures rapid encoding (permitting real-time software encoding on Intel processor-based platforms without DSP chips or ASICs), a high degree of performance in the editing environment without specialty hardware, and proper scalability to encompass emerging digital formats, such as Cinema2K and 4K. CineForm files are typically compressed in the range of between 5:1 and 10:1, depending on both user preference and image complexity. This technology has been integrated into the capture environment (CineForm Intermediate and CineForm RAW file formats) and more importantly into the post-production environment, as used in CineForm's Prospect HD\*, Aspect HD\*, and Neo HD\* product families for the Microsoft Windows\* and Mac OS X\* platforms.

The effectiveness of the CineForm codec for achieving the fidelity benefits of uncompressed video within a compression-based workflow derives from its bigger picture perspective of the camera-through-post needs of broadcast and filmmaking professionals. Because of the reduced file size and online workflow benefits pioneered by CineForm, a number of ISVs have integrated CineForm compression into non-linear editing and effects processing tools over the last few years. This list includes Adobe Premiere Pro\*, Sony Vegas\*, and others. CineForm offers compatibility with many more NLE and compositing packages, including Adobe After Effects\*, Autodesk Combustion\*, and Apple Final Cut Pro\*.

David Taylor, chief executive officer at CineForm, commented on the performance requirements of their products and the necessity for optimization with the latest hardware platforms. "To achieve CineForm's high level of real-time performance," Taylor said, "we have optimized our code to the fullest extent possible. As soon as Intel provides an additional processor cycle or memory transfer cycle, we immediately put it to good use with our algorithms. To assist us in this effort, Intel has offered guidance and tools, plus assistance from applications engineers when necessary as we optimized our software. Images in the content creation world keep getting bigger and require more processing power, so we expect the trend of using everything we can get from Intel processors to continue."

For more information, visit [www.cineform.com](http://www.cineform.com).



CineForm algorithms and workflow are compatible with many popular NLE applications, such as Adobe Premiere Pro\* (shown), Sony Vegas\*, Autodesk Combustion\*, and Apple Final Cut Pro\*.

## Processor-Based Design Architectures

A trend increasingly prevalent in the industry capitalizes on the flexibility and development advantages of software-based functionality. Instead of relying on special-purpose ICs—ASICs, DSPs, GPUs, FPGAs—and similar devices, the necessary functionality is programmed and implemented through multi-core processor architectures. The SI-2K camera is an example of this design paradigm, using the built-in capabilities of an Intel® Core™2 Duo processor to perform on-camera tasks that require a good deal of processing power, such as the real-time encoding of the video data to CineForm RAW format.

When algorithms are improved or additional functionality is needed, new software can provide the equivalent of a new model of the camera. A similar renaissance in design thinking is being observed in other fields, such as computer animation where ray tracing is being employed using a multi-core processor to perform the graphics algorithms associated with lighting, shadow generation, and frame rendering. Application design where individual processor cores can be devoted to delivering functionality that used to require specialized hardware provides substantial flexibility to developers. This approach not only shortens development cycles, but it also increases the useful life of hardware platforms as new design implementations can be achieved by updating the software, without requiring a re-engineered hardware platform.

## Silicon Imaging

Professionals working in cinema, commercials, corporate, and other areas of digital video production find that the Silicon Imaging SI-2K\* camera adds new levels of versatility, image integrity, and previewing possibilities to their everyday work processes. The SI-2K camera head, the Mini, operates independently of the camera body, opening up many possibilities for compact camera placement. The single-chip, two-thirds-inch sensor in the Mini, in combination with capture hardware and a Gigabit Ethernet interface, can deliver raw video data (at 12 bits per pixel) to the 2K body or an external computer.

The SI-2K body, powered by an Intel® Core™2 Duo processor, includes a removable hard disk drive and compact computer system running Silicon Imaging's own SiliconDVR software. The SI-2K body is equipped to convert the 12-bit linear raw data to a 10-bit logarithmic format, produce real-time, graded preview video using IRIDAS .Look files, and perform CineForm RAW Wavelet compression for storing content on the removable hard disk drive. A built-in touchscreen interface simplifies access to the many tools available to the camera operator and replicates the controls available when SiliconDVR is running on an external system, such as a notebook computer or production workstation. Controls and tools for focusing, setting exposures, previewing color options, and managing files can all be accessed through this user interface.

Steve Nordhauser, vice president of product development at Silicon Imaging, sees a variety of ways this digital video camera will improve operations for users. "For the typical user," Nordhauser said, "the



**The SI-2K\* digital video camera establishes a new price-point milestone for high-resolution video capture and integrates into new digital video workflow environments that are enhancing moviemaking.**

SI-2K represents both a simplification and an extension of current operating methods. A key concept in the structure of CineForm RAW files is its ability to record camera metadata. The RAW sensor data is kept pristine during capture, compression, and storage. All data modifiers (white balance, colorization) are stored in a metadata table inside the files with values that can be applied to the video temporarily or permanently removed from the data. Key decisions that might, on other cameras, ruin a video clip are deferred to post production. This greatly simplifies on-set capture and better integrates the camera into the overall workflow of the production."

For more information, visit [www.si-2k.com](http://www.si-2k.com).



## Wafian

The Wafian HR-1\* provides 10-bit 4:2:2 direct-to-disk video recording—the first CineForm-based, high quality compression product in the industry. Designed and manufactured in collaboration with Avnet, a portable version of this product, the HR-F1\*, includes hot-swappable media and support for battery power. The Wafian HR-F1 works effectively in the field, bringing new capabilities to video professionals operating on location in isolated environments. For even higher resolution recording, the Wafian HR-2 is a dual-link, 10-bit recorder for recording 4:4:4 video content as is used in digital cinema applications. Rounding out the product family, the HR-2-DS\* is a dual-stream, stereoscopic, 10-bit recorder that allows users to record and play back full HD 3-D video.

Wafian video recorders fit very neatly into the production portion of the workflow, recording HD video direct-to-disk at high resolutions. Using CineForm Wavelet compression, these recorders maintain the image fidelity essential to high-caliber professional work. As recorded video is being captured or played back, it can be viewed on a front-panel LCD or monitored by connecting the recorder to a separate external display. The tremendous storage capacity allows continuous recording of live events, with time durations of 18 hours and beyond supported with full mirroring.

Multi-threading techniques that fully exploit the available processor cores in the Wafian HR-1 and HR-2 video recorders contribute to exceptional performance capabilities that support recording at higher bit rates and frame resolutions. Wafian engineers also took

advantage of Intel® Matrix Storage Manager capabilities, providing a configuration option in the HR-1 and HR-2 recorders to enable internal RAID storage and provide recording redundancy. The Intel® C++ compiler and Intel® VTune™ Performance Analyzer were also used during the product development process.

Jeff Youel, president of Wafian, said, "Recording high-definition video presents a variety of challenges to the engineer. Managing the large number of taxing and simultaneous tasks is difficult, and the resulting product requires extreme stability even during extended periods of use. Intel's technology has empowered our engineers with the ability to make all of this transparent to the end user, and to create products that differentiate Wafian from other video acquisition companies."

For more information, visit [www.wafian.com](http://www.wafian.com).



The Wafian HR-2\* supports digital cinema applications with 10-bit 4:4:4 video recording.

## Production on the High Seas

The direct-to-disk video recording process was recently tested on the high seas, as Robert Margouleff of Mi Casa Multimedia, an audio post facility based in Los Angeles, began work on a documentary about tall ships, replicas of the sea-going vessels of the 18<sup>th</sup> and 19<sup>th</sup> century. Using Wafian HR-1 and HR-F1 HD Video Recorders and CineForm editing software, Margouleff has now completed production of episodes for the 12-part series, slated for television broadcasting and Blu-Ray DVD release. The production experience highlighted the advantages of the Wafian video recording technology. During an extended session on the Lynx, a replica of an 1812 American Privateer, Margouleff captured over 15 hours of content and, upon returning to the studio in Los Angeles, began immediately working with the high-definition material in the editing suite.

For many days, Margouleff and his team lived aboard the Lynx. During extended shooting sessions, the HR-1's ease of use and touchscreen LCD for real-time monitoring and immediate playback gave confidence to the Mi Casa team and improved the efficiency of operations.

Once back on land, Margouleff knew the post production would be equally efficient. Mi Casa engineers copied the footage from the Wafian into their Adobe Premiere workstation and began editing. No digitizing or importing was required. Mi Casa's Associate Producer Dana Sol said, "We never have to down convert or offline in our workflow. Once we're editing, it's high def all the time."

Mi Casa Multimedia continues to use the Wafian HR-1 as an integral part of their workflow. Another documentary film that was created using this proven workflow, *Chase Boat*, is scheduled for release soon.

## IRIDAS

Tuned for optimal performance with platforms based on Intel® Core™ microarchitecture and refined to capitalize on Intel® Streaming SIMD Extensions 4 capabilities, the IRIDAS SpeedGrade applications perfectly complement digital production and post-production workflows. With the IRIDAS .Look file format, which consists of non-destructive image adjustments and sharable metadata, SpeedGrade provides a genuine end-to-end “color pipeline,” allowing colorists, cinematographers, and directors to easily communicate creative looks.

In 2007 IRIDAS achieved a breakthrough in the industry with the first real-time de-Bayering of RAW footage. IRIDAS currently offers live playback of all available native RAW formats, including CineForm RAW. RAW files are one-third the size of standard RGB formats and contain greater image data latitude. The flexibility of RAW workflows, combined with the advantages of the .Look file format, let users develop, exchange, and apply color metadata to their images throughout the entire filmmaking process.

Perhaps the simplest starting point for this type of workflow is a still-frame application called SpeedGrade OnSet. With SpeedGrade OnSet, directors and cinematographers can establish the creative look—even on a laptop. The resulting .Look files are tiny metadata instruction sets, which can be applied to images non-destructively. CineForm, for example, supports use of .Look files in editing applications so that editors can view images the way the director wants them to appear. Silicon Imaging has implemented SpeedGrade OnSet right in the SI-2K camera so looks can be applied and adjusted in the viewfinder.

Going beyond the limitations of the viewfinder LCD, any SpeedGrade application can be linked by means of Ethernet to an SI-2K camera



Before and after images in IRIDAS SpeedGrade\* DI. Clicking on a .Look at the bottom of the screen applies the .Look non-destructively to the footage and brings up all the settings used to create it in the grading panel.

or another computer running SiliconDVR and used to edit .Look files dynamically. For example, the cinematographer can grab stills from the camera, use that image to apply color adjustments creating a specific .Look, and then upload the .Look metadata back into the camera. The IRIDAS development team used their membership in the Intel® Software Partner Program to tap into the expertise and knowledge of Intel engineering. They gained particular benefits from the use of Intel® Performance Primitives to achieve cross-platform decoding of .jpeg format files. The team also took advantage of Intel Streaming SIMD Extensions 4.1 instructions to increase performance in parts of their solution subsystem, doubling the speed in comparison with Intel Streaming SIMD Extensions 3 routines.

For more details about IRIDAS SpeedGrade DI and SpeedGrade OnSet, visit [www.speedgrade.com/di/](http://www.speedgrade.com/di/) and [www.speedgrade.com/onset/](http://www.speedgrade.com/onset/).

*“Providing the necessary horsepower on latest-generation hardware puts a high-end filmmaking system like SpeedGrade\* DI into the hands of artists and facilities who could otherwise never hope to afford these capabilities. For larger facilities, this means that grading and finishing are no longer restricted to the end of the process, alleviating all the pressure that goes along with that. Color work can now realistically be done in parallel with the whole filmmaking process. Through the latest processor technologies, Intel is supporting these revolutionary new techniques for digital cinema workflows and positively impacting the quality of the films we watch and love.”*

— Lin Kayser, CEO and Founder, IRIDAS

*"I absolutely love the approach that SI is taking, instead of reinventing the wheel, like the equipment needed to process images, they are concentrating on making sure that the image creation part works as well as it can and then they work with specialist partners and their products: Intel® Core™2 Duo processors to handle the data they create, CineForm to compress it, IRIDAS for color grading, and P+S Technik to add film functionality."*

— Geoff Boyle, FBKS, Director of Photography, *Dark Country*

### **Dark Country: 3-D Moviemaking Direct-to-Disk**

As an example of the capabilities of the SI-2K camera in the increasingly important 3-D movie space, the film *Dark Country* was created using tandem SI-2K Mini camera heads with the captured content directed to two recording systems mounted on a custom rig supplied by ParadiseFX Studios. The capture requirements are significantly more complex when using 3-D techniques, and removing the SI-2K camera heads from the camera bodies and individually placing them simplified the alignment, both while using prism systems and while viewing the dual image capture directly.

High-end computers linked to the cameras by means of the Gigabit Ethernet interface were used for capture. An individual computer recorded each view of the scene, including IRIDAS .Look files. Content was captured to CineForm RAW files, with review and pre-grading done directly in SpeedGrade using the unrendered RAW format.

The ability to render 3-D Look-Up Tables internally within the camera is a major enhancement to the production process and possible because of the built-in processing power embedded in the camera. Rather than being locked into white balance and color control settings selected prior to capture, as is the case with many cameras, the SI-2K makes effective use of the metadata stored in the CineForm RAW files. The .Look files provide a dynamic visualization of the color modifications being employed without affecting the pristine source files. The SI-2K has the unique capability of being able to preview the images in the viewfinder and on-screen monitors as they appear with a selected .Look file applied. During the recording of the images, the selected .Look file becomes the metadata for the image sequences.

The experience during the production of *Dark Country* demonstrates that high-quality stereoscopic filmmaking can be done on a relatively modest budget and suggests design improvements for future 3-D work—thanks in no small measure to the real-time stereo grading capabilities of SpeedGrade, the ability to perform live de-Bayering of the CineForm RAW format, and the software-based design of SiliconDVR. An updated version of SiliconDVR will include support for concurrently capturing two data streams. Additional enhancements to the software will make it easier for moviemakers to set up and shoot 3-D movies.



The SI-2K Mini cameras in a stereo rig as used in *Dark Country*.

## Moving Forward

The common denominator that underlies all the processes that are dramatically improving digital workflow is CineForm compression. Capturing, processing, and storing digital images at extremely high resolutions—without degradation of the visual quality—opens up a range of unprecedented production and post-production capabilities. CineForm RAW in the SI-2K camera provides an ideal acquisition format. CineForm Intermediate, as used in Wafian video recorders, maintains the pristine image properties for storage. CineForm's editing tools—the Prospect and Neo families—take advantage of these same capabilities, as well as IRIDAS SpeedGrade DI for finishing. Finishing encompasses assembly, color grading, and final rendering for public presentation in various viewing environments, such as theatrical release, broadcast, DVD, and so on. Each stage of the workflow benefits from these compression algorithms, without sacrificing the fidelity or richness of the image content.

The momentum behind digital cinema and digital video production systems continues to grow as each successive hardware platform fuels additional software advances and increased performance, making it possible to work effectively with larger frames, more complex effects, and more fully integrated post-production pipelines that reduce the barriers and the time lag between video capture and the application of image enhancements and effects. Within this type of seamless production environment, moviemakers enjoy new creative freedom and the ability to create visually rich, imaginative scenes that do not compromise quality or image fidelity in any way. Within this fertile environment, innovators and artists are industriously working together to create documentaries, movies, training materials, and other works of imagination to entertain, educate, and enlighten. This trend shows every sign of reaching even greater heights as new technology platforms—powered by reliable, high-performance Intel® architecture components—become available and multi-core architectures are superseded by even more powerful many-core designs.

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## For More Information

CineForm:

[www.cineform.com](http://www.cineform.com)

Silicon Imaging:

[www.si-2k.com](http://www.si-2k.com)

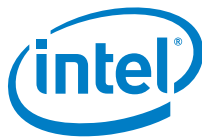
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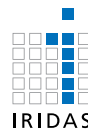
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