

Canon

EOS-1D X MARK III

WHITE PAPER



Renaissance in Video Acquisition

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EOS-1D X Mark III

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ABSTRACT

The Canon EOS-1D X Mark II has long stood as a global benchmark in professional DSLR cameras. Combining multiple cutting-edge technologies like Dual Pixel CMOS Autofocus, advanced image sensor and image processing, and both still and motion image recording technologies, it has well served the global marketplace.

But, the rapid advances in video production and delivery technologies — combined with totally new video-based business — are propelling a global voracious appetite for more powerful flexibilities in video capture. For instance, vlogging continues to expand the creativity of huge numbers and their associated internet sharing; multiple web-based services are spawned almost daily; advertising is going digital at an astounding pace; professional photographers continue to find flanking new video-based businesses; and television news coverage continues to broaden.

Separately, the past five years have seen the rapid adoption of the mirrorless alternative to the established optical viewfinder-based DSLR. But, that still remains a gigantic global base and many are not ready to let go of a long familiarity with the DSLR that has served so many, so well. Canon has definitively stepped into the mirrorless world and has a firmly established roadmap to serve this growing constituency with both R-mount lenses and cameras. Nevertheless, a still well-defined parallel domain of DSLR and mirrorless has dictated a major development into a whole new-generation DSLR — and that is the EOS-1D X Mark III — the topic of this paper.

A dramatic leap forward in video capture stands as one of the central design strategies of the EOS-1D X Mark III. This white paper focuses exclusively on this topic. Two separate white papers cover the still-imaging and networking features of this important new product.

1.0 INTRODUCTION

The professional EOS-1D X DSLR camera was announced in 2011 and started delivery in 2012. It had a full-frame CMOS sensor of 18 megapixels (MP), versus the 16MP APS-H sensor of the EOS-1D Mark IV; an ISO of 51,200 versus 12,800 of the 1D Mark IV; and 12 fps top shooting speed versus the 10 fps of its predecessor during viewfinder shooting. Its video capability supported capture of HDTV — both formats of 1080P at 24 / 25 / 30 fps and 720P at 60P.

The EOS-1D X Mark II arrived in 2016 — offering a 20.2 Megapixel full-frame sensor incorporating Dual Pixel CMOS Autofocus, the same 61-point AF module but augmented by Ai Servo III+, 14 fps maximum shooting speed and more accurate exposure due to a new 360,000 pixel RGB and IR sensor with 216 metering zones. The Mark II has a touchscreen for use in live view/video mode. It captures 4K up to 59.94P (Motion JPEG at approximately 800 Mbps in MOV file format) and Full HD up to 119.9 fps — a significant step forward over the 1080P at 30 fps in the EOS-1D X.

In 2020, Canon introduced the EOS-1D X Mark III as a successor to the EOS-1D X Mark II. It uses a similar, but improved, 20.1 Megapixel CMOS image sensor. It is a stop higher in sensitivity and has lower noise, primarily due to a new and more powerful DIGIC X processor. Autofocus has been elevated on a number of fronts. Through the viewfinder, it has a 191-point AF module versus the 61 of the predecessor in still shooting, and can operate from Ev-4 to 21 (maximum). Head detection has been added as an alternative to Face Detection, and is especially useful in situations where faces become partially or fully obscured.

On the imaging and recording fronts, the EOS-1D X Mark III boldly steps forward. In image capture, the EOS-1D X Mark III adds a powerful alternative to 8-bit JPEG for still photography, in the form of the 10-bit HEIF codec. It also adds a C-Raw option to RAW — allowing smaller file sizes. It improves HDR functionality for still photo shooting in the form of the standardized PQ system. On the video side, it boasts optional OETFs that include Canon Log — allowing the EOS-1D X Mark III to be a companion camera within a Cinema EOS production system.

The powerful internal recording of the still photo and multiple video options is made possible by the new codecs — all operating at high data rates — further empowered by the dual CFexpress cards that are utilized in the EOS-1D X Mark III.

One of the most significant advances of the EOS-1D X Mark III is its video acquisition capabilities. Full 5.5K RAW video can be internally recorded up to 60 fps. This is not available in the EOS-1D X Mark II.

The full-frame sensor also creates uncropped 4K, offering a choice of either the cinema-centric 4K DCI [1] or the broadcast television-centric 4K UHD [2] — both exploiting the full width of the sensor (the 16:9 UHD is cropped from the 17:9 DCI format). These are simultaneously recorded on a second memory card. They are recorded as YCbCr 4:2:2 at 10-bit at all of the standard frame rates up to 60P using the MPEG-4 HEVC/H.265 codec at high data rates (as opposed to the Motion JPEG of the EOS-1D X Mark II) — when the Canon Log OETF is selected. They can alternatively be recorded as YCbCr 4:2:0 at 8-bit using the MPEG-4 AVC/H.264 codec (when Canon Log is switched OFF).

In addition, a cropped 4K DCI from the central portion of the image sensor can be created and recorded at frame rates up to 60P. Full 16:9 1080P HD, capitalizing on the full sensor width, can be recorded up to 120P.

2.0 DIGITAL IMAGE FORMAT OPTIONS IN THE EOS-1D X MARK III

2.1 Full-frame 20.1 Megapixel CMOS Image Sensor

The CMOS image sensor in the EOS-1D X Mark III can be likened to a large canvas on which a variety of image formats can be drawn. It is rich in spatial sampling — with 5600 x 3730 active photo sites available to support various motion imaging formats that meet international digital production standards. This flexibility is central to the powerful video recording options available in the 1D X Mark III.

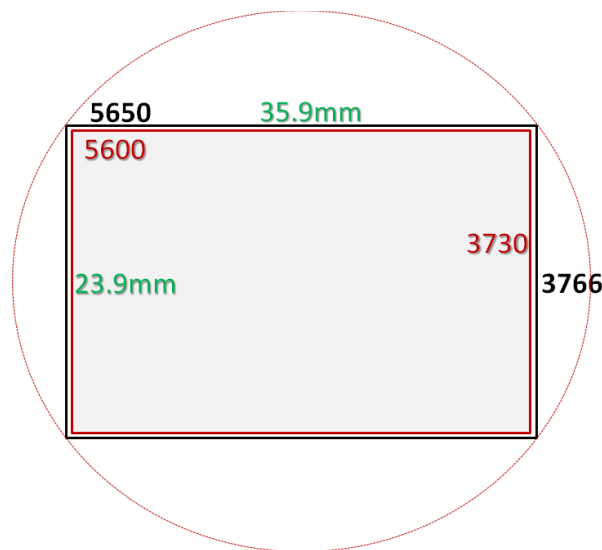


Figure 1 The full-frame image sensor used in the EOS-1D X Mark III showing total and active photo site counts

2.2 Video Options in the EOS-1D X Mark III

The Mark III's overall design has added significant extensions to its video recording capabilities. Recognizing that contemporary professional DSLR cameras have both 4K and HD video imaging that are invaluable as supporting B and C cameras on major movie and television productions, the EOS-1D X Mark III has the option of either the movie-centric 4K DCI production format or the television/web-centric 4K UHD production format, as well as the Full HD format.

When used with a full-frame lens, the EOS-1D X Mark III has a menu selection that switches Image Sensor Readout modes between the following five motion imaging formats:

1. 5.5K RAW Video with a 17.9 aspect ratio — at frame rates of 59.94 / 50 / 29.97 / 25 / 24 / 23.98 fps
2. 4K DCI (4096 x 2160) with 17:9 aspect ratio — with no cropping — at frame rates of 59.94 / 50 / 29.97 / 25 / 24 / 23.98 fps
3. 4K UHD (3840 x 2160) with 16:9 aspect ratio — with no cropping — at frame rates of 59.94 / 50 / 29.97 / 25 fps

4. 4K DCI (4096 x 2160) with 17:9 aspect ratio — having a 1.3x crop — at frame rates of 59.94 / 50 / 29.97 / 25 / 24 / 23.98 fps
5. Full HD (1920 x 1080) — with no cropping — at frame rates of 119.9 / 100 / 59.94 / 50 / 29.97 / 25.0 fps

2.3 Details of the Digital Video Format Options

The optional video formats separate into five basic choices, all taking full advantage of the large full-frame image sensor. The three high-end formats are as follows:

- 5.5K RAW video format (5472 x 2886) having the cinema-centric aspect ratio of 17:9. This format is illustrated in green in Figure 2.

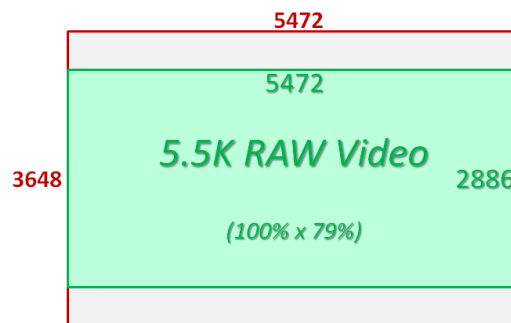


Figure 2 Showing the angle of view (%) and the recording size of the 5.5K RAW video image format

- 4K DCI video format (4096 x 2160) having the cinema-centric aspect ratio of 17:9 [1] — derived from the full horizontal sampling structure of the full frame image sensor — generally termed an uncropped image structure. This format is illustrated in blue in Figure 3.

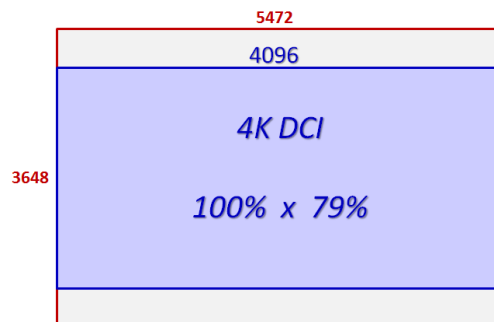


Figure 3 The angle of view (%) and recording size of the uncropped full frame 4K DCI video image

- 4K UHD video format (3840 x 2160) having the television centric aspect ratio of 16:9 — derived from nearly the full horizontal sampling structure of the image sensor. This format is illustrated in yellow in Figure 4.

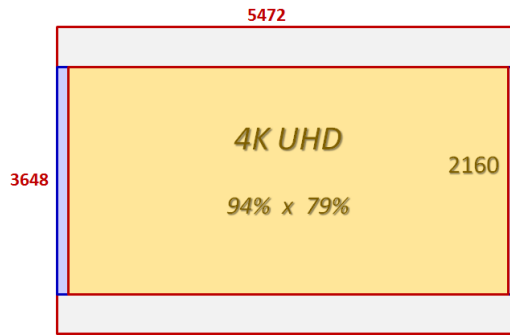


Figure 4 The angle of view (%) and recording size of the full frame 17:9 aspect ratio 4K UHD video image

It is important to note that the 4K DCI digital video format is derived from the original 5.5K readout using Canon's Oversampling 4K Processing [3]. In turn, the 4K UHD format is simply cropped slightly to the 16:9 aspect ratio from the 17:9 aspect ratio 4K DCI format. The choice of these three video formats offer important flexibilities in high-end motion imaging origination. The EOS-1D X Mark III camera can now be readily integrated into a cinema production system (as an auxiliary B or C camera), working with professional digital cinema cameras that are recording in RAW or in 4K DCI. The camera can also be integrated into a broadcast television production that is working in 4K UHD.

In addition to these three video formats, the EOS-1D X Mark III offers two additional options:

- 4K DCI video format (4096 x 2160) directly cropped from the center of the 5.5K image sensor (for example, if a Super 35mm lens is employed) as shown in blue in Figure 5.
- Full HD (1920 x 1080) having the standardized 16:9 aspect ratio — derived from the full horizontal sampling structure of the full-frame image sensor.

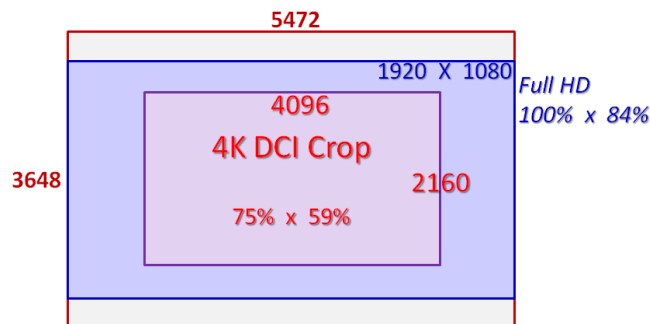


Figure 5 The angle of view (%) and recording size of the 4K DCI Crop and the Full HD video image

3.0 VIDEO RECORDING

3.1 Video Recording Options

In addition to extending the choice of video format options, the EOS-1D X Mark III elevates the recording performance of each, while also extending their respective recording durations. This was made possible by the employment of a relatively new advanced memory card — the CFexpress card.

These cards are specifically intended to support both RAW video recording and high bit rate compressed video formats. Recognizing the pace of advances in video data rates (especially at higher frame rates), Canon decisively adopted these innovative new memory cards. The 1D X Mark III internally records all of the following options (this paper will explain how each is selected and the all-important point that the Canon Log OETF must be selected when recording in the 10-bit HEVC Mode):

- 5.5K RAW video
- 4K DCI — uncropped — YCbCr 4:2:2 @ 10-bit using the data-efficient MPEG-4 / H.265 HEVC codec
- 4K DCI — uncropped — YCbCr 4:2:0 @ 8-bit using the well-established MPEG-4 / H.264 AVC codec
- 4K DCI — cropped — YCbCr 4:2:2 @ 10-bit using the data efficient MPEG-4 / H.265 HEVC codec
- 4K DCI — cropped — YCbCr 4:2:0 @ 8-bit using the well-established MPEG-4 / H.264 AVC codec
- 4K UHD — uncropped — YCbCr 4:2:2 @ 10-bit using the data efficient MPEG-4 / H.265 HEVC codec
- 4K UHD — uncropped — YCbCr 4:2:0 @ 8-bit using the well-established MPEG-4 / H.264 AVC codec
- Full HD YCbCr 4:2:2 @ 10-bit using the MPEG-4 / H.265 HEVC codec
- Full HD YCbCr 4:2:0 @ 8-bit using the MPEG-4 / H.264 AVC codec

3.2 Recording Media

Anticipating the unceasing demands for high-density data storage, the CompactFlash Association has developed the new CFexpress memory card; this was announced in early 2019 [4]. Final standardization of these cards by CFA is anticipated in early 2020. The CFexpress 2.0 will feature three distinct physical card sizes: Type A, Type B and Type C. The EOS-ID X Mark III uses the Type B memory card.




	Type A	Type B	Type C
Dimension	20mm x 28mm x 2.8mm 	38.5mm x 29.8mm x 3.8mm 	54mm x 74mm x 4.8mm 
PCIe® Interface	Gen3, 1 lane	Gen3, 2 lanes	Gen3, 4 lanes
Stack	NVMe™ 1.3	NVMe™ 1.3	NVMe™ 1.3
Maximum Theoretical Performance	1000MB/s	2000MB/s	4000MB/s

Figure 6 The newly standardized CFexpress 2.0 cards come in three sizes and associated specs

By 2019, some five companies had already announced CFexpress cards: Apacer, Delkin, Lexar, ProGrade Digital and SanDisk. SanDisk recently announced their Type B card — now accepted by Canon and shown in Figure 7.



Figure 7 Showing one of the first CFexpress cards accepted by Canon in 2019

To support development work on high-end television or movie productions, the EOS-1D X Mark III records the master file as 5.5K RAW on one CFexpress card, while simultaneously recording a high-quality secondary 4K MP4 on the second CFexpress card (note that during RAW recording, only one CFexpress card can have 5.5K RAW files written to it, even if two are installed).



Figure 8 Simultaneous recording of the Master 5.5K RAW and an MP4 4K format

3.3 Optoelectronic Transfer Function (OETF) — Canon Log

Inherent to the new recording strategies of the EOS-1D X Mark III is the utilization of the professional cinema Canon Log OETF that supports internal 4K YCbCr 4:2:2 @ 10-bit depth recording. This ensures faithful capture of the full 12 T-stop exposure latitude of the image sensor, while lowering the total data payload to be recorded.

Canon had developed a logarithmic image data representation for the Cinema EOS C300 and C500 cameras, tailored to optimize the capture of the wide dynamic range of the CMOS sensor employed in these cameras. This optoelectronic transfer function (OETF) is labeled the Canon Log characteristic. Canon Log is a perceptually uniform digital transfer characteristic that transforms, within the camera processing system, the high bit depth per RGB color component linear output of the A/D converters into a quasi-logarithmic nonlinear transfer function.

In the postproduction domain, Canon Log can be transformed back to the linear domain to facilitate such digital processes as color matrix transformations, secondary color correction, luminance tonal adjustments, image compositing, etc. This transformation enables wide dynamic range digital intermediate processes to be performed in linear light space with minimum quantization errors.

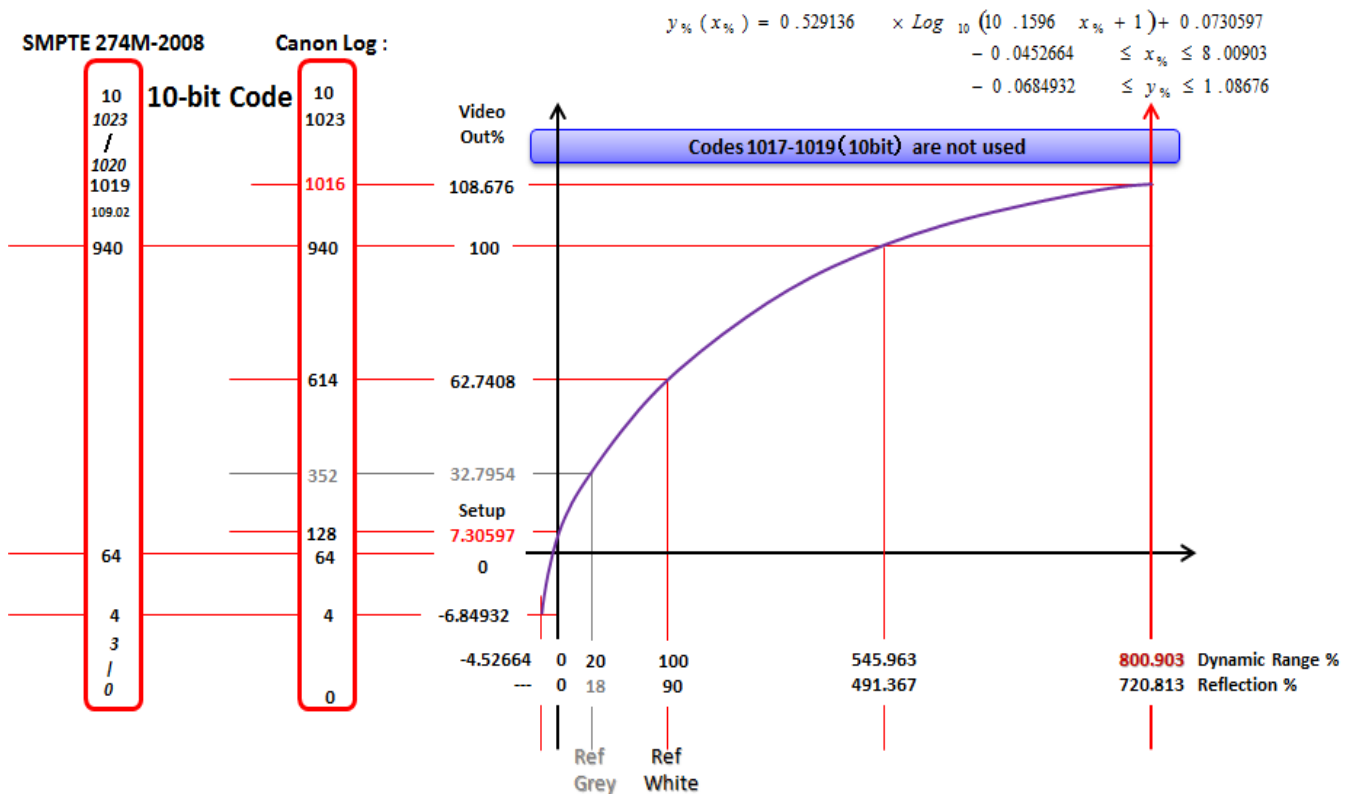


Figure 9 Showing the 10-bit coding and the precise mathematical representation of the Canon Log OETF

The EOS-1D X Mark III incorporates 10-bit Canon Log encoding as the primary OETF, which empowers the camera to closely match imaging characteristics of the Cinema EOS cameras. This OETF is used for all of the P / Tv / Av / M exposure control modes as well as in the ISO Auto setting mode. The OETF supports an 800% dynamic range, based upon Base ISO 400.

3.4 5.5K RAW Recording

At the very high end, the camera supports RAW recording of the full 5.5K motion imaging data from the image sensor at frame rates up to 59.94 fps. By protecting all of the data read from the image sensor, the RAW recording offers greater latitude in editing, color correction and tonal manipulation (better gradation in highlights and shadowed areas), without image deterioration. The 12-bit depth ensures excellent picture sharpness, wide dynamic range and superb tonal reproduction.

Table 1 summarizes the key recording parameters of the 5.5K recording system. This high-resolution format is recorded at a 12-bit depth at all of the internationally standardized frame rates up to a maximum of 59.94 fps (at this frame rate, the data rate is 2600 Mbps). A related simultaneous recording video is recorded using the MPEG-4/H.264 codec with an MP4 file wrapper. If the professional cinema Canon Log OETF is deployed, that simultaneous recording video will be recorded at a 10-bit depth. This level of image quality supports creative decision-making in the offline work. The accompanying audio recording is Linear PCM.

TABLE 1 5.5K RAW Video Recording Specifications

RAW Video	Container Format	Resolution	Bit Depth	Frame Rate (fps)	Data Rate (Mbps)	Simultaneous Recording		Audio
						OETF		
5.5K RAW	CRM	5472 x 2886 DCI 17:9 Aspect Ratio	12	59.94 / 50	2600	Canon Log ON	MP4 10-bit	Linear PCM
				29.97 / 25 / 24 / 23.98	1800	Canon Log OFF	MP4 8-bit	

In the event of Canon Log not being active, the simultaneous MP4 recording will be at an 8-bit depth. An alternate to the standard BT.709 OETF is to switch in the D+ curve — otherwise known as Highlight Tone Priority. The difference between these three OETF's is shown in Figure 10.

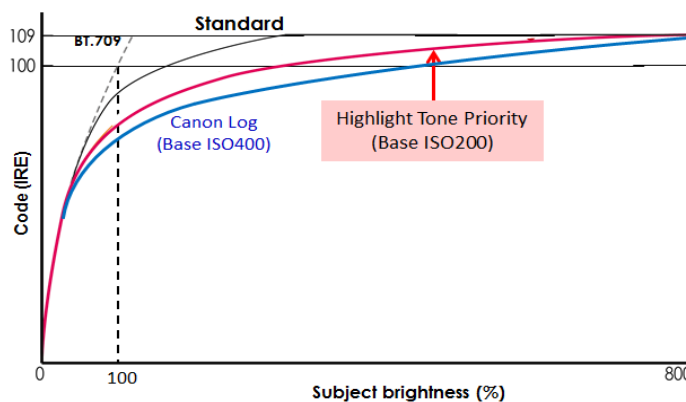


Figure 10 There are three choices of OETF for the parallel recorded MP4 video recording

While the bit rate reduction strategy used in the creation of the 5.5K RAW file format is very effective (reducing the file size by a factor between 3 and 5, depending upon the level of detail in the scene and its temporal resolution), the recorded files are still quite large as shown in Table 2.

However, as outlined in this table, the storage prowess of the new CFexpress memory cards supports highly practical recording durations.

TABLE 2 Data Rates, File Sizes and Recording Durations for 5.5K RAW

Video Recording	Resolution	Frame Rate (fps)	File Size (MB/min)	Data Rate (Mbps)	Recording Duration (Minutes) CFexpress Card		
					64GB	256GB	1TB
5.5K RAW	5472 x 2886	59.94 / 50	18711	2600	3	13	50
		29.97/25/24/23.98	12937	1800	4	18	73

Imaging attributes of the 5.5K RAW video recording are dependent upon some of the camera settings. These largely bear upon the handling of highlights. They are summarized in Table 3.

TABLE 3 5.5K RAW Video Attributes as a Function of Camera Settings

Mode Select Settings	Equivalent to Still Image #1	Equivalent to Still Image #2	Priority to Highlights #3
Highlight Tone Priority	OFF	D+ / D+2	----
Canon Log	OFF	OFF	ON
Base ISO Speed	100	200	400
Monitoring Image (while shooting)	Possible Blown-out Highlights	Reduced Blown-out Highlights	Priority to Highlights

Mode #1 can lead to significant blown-out highlights, but has the lowest noise level. Mode #3 offers the best highlight handling but at the expense of elevated noise. Mode # 2 lies between #1 and #2 in terms of highlight handling and noise level.

3.5 4K and HD Recording Strategies

Separate to the high-level 5.5K RAW option described, the EOS-1D X Mark III offers a number of alternative options that focus on the recording of the standardized digital production formats, and for Full HD using more data-efficient recording codecs. A core design decision in the EOS-1D X Mark III was to move forward from the cropped 4K Motion JPEG with the MOV file format of the EOS-1D X Mark II, and now to base uncropped 4K and HD image capture upon the globally established MPEG-4 AVC/H.264 compression algorithm and use the MP4 file format as the container. This reflects the important goal of the EOS-1D X Mark III to offer very low-cost and extended duration recording of

very good quality 4K YCbCr 4:2:0 @ 8-bit to support a multiplicity of applications — for professional newsgathering and low-budget documentaries, website productions and, of course, home video productions.

A bolder strategy was to also offer an alternative codec that propels on-board recording of 4K to a higher performance level — by including the option of using the relatively new MPEG-4 HEVC/H.265 compression algorithm, to elevate the recording of 4K to the full production level of YCbCr 4:2:2 @ 10-bit at frame rates up to 59.94 fps.

3.5.1 MPEG-4 AVC/H.264 Codec

The standardized H.264/MPEG-4 codec can be selected to record the two variants of 4K or Full HD. MPEG-4 AVC/H.264 is a sophisticated compression standard that is divided into several “Parts”. The specific “Part” pertaining to the EOS-1D X Mark III codec is MPEG-4 Part 10 — known as MPEG-4 Advanced Video Coding (AVC). It is a video coding standard developed by the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG). It is also one of the most commonly used formats worldwide for the recording, compression and distribution of video content. The specific goal of the MPEG-4 AVC/H.264 standard was to provide subjectively excellent video quality at substantially lower bit rates than previous standards, like MPEG-2. Those lower bit rates facilitate very long recording durations on the CFexpress memory cards.

In its approach to compression, this codec manages two forms of groups of pictures (referred to as GOP): intra coded frames and inter coded frames. The two are formally known as Intra-frame or Long GOP. The Intra-frame (often referred to as “Intra” or “I-frames”) is a self-contained frame that is independently decoded without reference to other frames. Each frame is individually compressed. This entails a high data rate for recording — but it does expedite high quality in sequences entailing fast motion, while also more easily supporting editing and any video processing in postproduction.

Long GOP, on the other hand, uses both intra coded and inter coded frames — with the inter coded frames identified as P- or B-frames. The P-frame, which stands for predictive inter frame, makes references to parts of an earlier I-frame and/or P-frame(s) to code the frame. B-frame, or bi-predictive inter frame, is a frame that makes references to both an earlier reference frame and a future frame. This mode compresses some selected complete I-frames, with intervening frames representing differences in scene content of subsequent consecutive frames — and accordingly, comprises considerably lower data than I-frames. The number and sequence of the intervening P- and B-frames is dependent upon specific bit rate reduction strategies. This strategy allows exploitation of temporal redundancies to significantly lower data rates. The long GOP is particularly data efficient while still providing a high video quality.

H.264 processes all of these frames of video using a block-oriented, motion-compensation-based video compression standard, whose units are called macroblocks.

These two groups of pictures have different labeling in the larger video industry — as outlined here:

Industry Labeling of Intra Coded Frames

Intra; I-frames; All-I

Industry Labeling of Inter Coded Frames

These also are referred to in different ways: Long GOP; IPB

Because the video recording in the EOS-1D X Mark III encompasses professional digital 4K formats (DCI and UHD), this white paper will use the labeling known in professional production communities. Intra coded frames will be labeled as Intra. Inter coded frames will be labeled as IPB.

Technically, MPEG-4 AVC/H.264 is a powerfully effective compression system having broad flexibilities — embodying the concept of “Profiles” and “Levels” — which is intended to support

specific sets of performance levels and technical capabilities that can be tailored to a very wide range of applications.

Within each of the profiles there are multiple technical strategies relating to the overall compression format. Different profiles can be combined to formulate a certain level of performance and operational dexterity that can be tailored to different applications. Each of the associated levels specifies sets of constraints for key compression algorithm parameters. The combination is often referred to as the “Toolkit” of H.264 to structure a specific codec — in terms of application, performance *and cost*.

TABLE 4 MPEG-4 AVC/H.264 Profiles and Levels for 4K DCI Full Frame and Cropped

PROFILE	LEVEL	Frame	Prediction	Compression	Resolution 4K DCI	Bit Depth	Chroma Sample	Frame Rates	OETF	File Format
High	6.2	Full	Intra Frame	AVC H.264	4096 x 2160	8	4:2:0	59.94/50 29.97/25/24/23.98	SDR	MP4
High	5.1	Full	IPB Frame	AVC H.264	4096 x 2160	8	4:2:0	59.94/50 29.97/25/24/23.98	SDR	MP4
High	6.2	Crop	Intra	AVC H.264	4096 x 2160	8	4:2:0	59.94/50 29.97/25/24/23.98	SDR	MP4
High	5.1	Crop	IPB	AVC H.264	4096 x 2160	8	4:2:0	59.94/50 29.97/25/24/23.98	SDR	MP4

3.5.2 HEVC — High Efficiency Video Coding

The high level video compression codec used in the EOS-ID X Mark III is Canon’s implementation of HEVC. High Efficiency Video Coding (HEVC) is the latest video coding standard of the ITU-T Video Coding Experts Group and the ISO/IEC Moving Picture Experts Group (MPEG) organization’s standards [5]. It is sometimes referred to as MPEG-H Part 2 and ITU-T H.265. The primary goal of HEVC was to enable significantly improved compression performance relative to existing standards.

MPEG-4 HEVC/H.265 was designed to address most existing applications of MPEG-4 AVC/H.264, while specifically directing attention to two important issues:

1. Greater video resolution images (4K and 8K are the standardized production formats).
2. Increased use of parallel processing architectures.

HEVC incorporates many improvements over AVC. It evolved from the many prior MPEG strategies but has added greater levels of contemporary sophistication. On December 22, 2016, MPEG-4 HEVC/H.265 Version 4 was approved as an ITU-T standard. This codec also deploys Levels and Profiles to support picture quality improvements such as enhanced color gamut (BT.2020), higher bit depths (10-bit and beyond), high frame rates (50/60/100/120) and HDR. A Profile is a defined set of coding tools or algorithms used to structure a specific bitstream conforming to that profile. Levels are a set of constraints on key parameters of that bitstream — used to lower decoder processing load and memory requirements by limiting maximum picture size, maximum frame rate, maximum sampling bit rate, minimum compression ratio and other more detailed parameters. There are

multiple Levels, each specifying a maximum digital sample count and frame rate. For each Level, the Tier determines the output data bit rate.

HEVC was also optimized for progressive scan (unlike HD, which is largely interlaced) and this made it perfectly suited to the progressive scan 4K production standards.

TABLE 5 Profiles and Levels of MPEG-4 HEVC/H.265 for 4K DCI Full Frame and Cropped

PROFILE	LEVEL	Frame	Prediction	Compression	Resolution 4K DCI	Bit Depth	Chroma Sample	Frame Rates	OETF	File Format
Main 422-10	High Tier 6.2	Full Frame	Intra	HEVC H.265	4096 x 2160	10	4:2:2	59.94/50 29.97/25/24/23.98	Canon Log	MP4
Main 422-10	High Tier 5.1	Full Frame	IPB	HEVC H.265	4096 x 2160	10	4:2:2	59.94/50 29.97/25/24/23.98	Canon Log	MP4
Main 422-10	High Tier 6.2	Crop	Intra	HEVC H.265	4096 x 2160	10	4:2:2	59.94/50 29.97/25/24/23.98	Canon Log	MP4
Main 422-10	High Tier 5.1	Crop	IPB	HEVC H.265	4096 x 2160	10	4:2:2	59.94/50 29.97/25/24/23.98	Canon Log	MP4

Since 2013, the HEVC codec has been involved in worldwide tests and deployments across a wide range of applications that include OTT, VOD and satellite DTH. They included 4K UHD broadcasts where management of bandwidth and preservation of high image quality are especially important. These tests stimulated the expansion of the Levels, Profiles and Tiers of the HEVC standard to accommodate the multiple digital formats sought globally for both production and for distribution.

Features of the new compression system provide an important bit-rate saving for equivalent perceptual image quality relative to the performance of earlier standards — especially for high-resolution 4K video.

Profiles retain the same meaning as in prior standards — that is, specifying the diverse tools required for different applications.

The HEVC codec does entail increased complexity. For a given image format, it elevates processing complexity by a factor of 10 to 20 times. Given the extended resolutions that are supported, HEVC coding demands higher processing speed (implemented in either software or hardware). As a consequence, parallel processing is deployed, empowering separate processing engines to independently work on different regions of the image to expedite the many processing tasks.

TABLE 6 Profiles and Levels of HEVC/H.265 and AVC/H.264 for 4K UHD Full Frame

PROFILE	LEVEL	Frame	Prediction	Compression	Resolution 4K UHD	Bit Depth	Chroma Sample	Frame Rates	OETF	File Format
Main 422-10	High Tier 6.2	Full Frame	Intra	HEVC H.265	3840 x 2160	10	4:2:2	59.94/50 29.97/25	Canon Log	MP4
Main 422-10	High Tier 5.1	Full Frame	IPB	HEVC H.265	3840 x 2160	10	4:2:2	59.94/50 29.97/25	Canon Log	MP4
High	6.2	Full Frame	Intra	AVC H.264	3840 x 2160	8	4:2:0	59.94/50 29.97/25	SDR	MP4
High	5.1	Full Frame	IPB Frame	AVC H.264	3840 x 2160	8	4:2:0	59.94/50 29.97/25	SDR	MP4

TABLE 7 Profiles and Levels of HEVC/H.265 and AVC/H.264 for Full HD

PROFILE	LEVEL	Frame	Prediction	Compression	Resolution Full HD	Bit Depth	Chroma Sample	Frame Rates	OETF	File Format
Main 422-10	High Tier 5.1	Full Frame	Intra	HEVC H.265	1920 x 1080	10	4:2:2	119.88/100 59.94/50 29.97/25	Canon Log	MP4
Main 422-10	High Tier 5.1	Full Frame	IPB	HEVC H.265	1920 x 1080	10	4:2:2	119.88/100 59.94/50 29.97/25	Canon Log	MP4
High	6.2	Full Frame	Intra	AVC H.264	1920 x 1080	8	4:2:0	119.88/100 59.94/50 29.97/25	SDR	MP4
High	5.1	Full Frame	IPB	AVC H.264	1920 x 1080	8	4:2:0	119.88/100 59.94/50 29.97/25	SDR	MP4

4.0 RECORDING DETAILS

4.1 MPEG-4 AVC/H.264 — Data Rates, Files Sizes and Recording Durations

For both the 4K DCI and 4K UHD video formats, the MPEG-4/H.264 codec can be selected and the choice of Intra (All-I) or Inter (IPB) options is also selectable for all frame rates. Table 8 shows the associated recording data rates, file sizes and recording durations for all frame rates. 5.5K RAW is included as a reference.

TABLE 8 Data Rates, File Sizes and Recording Durations for each 4K format and Full HD

Video Recording	Resolution	Frame Rate (fps)	Codec	File Size (MB/min)	Data Rate (Mbps)	Recording Duration (Minutes) CFexpress Card					
						64GB	256GB	1TB			
5.5K RAW	5472 x 2886	59.94 / 50	<i>Proprietary</i>	18711	2600	3	13	50			
		29.97/25/24/23.98		12937	1800	4	18	73			
4K DCI Full Frame	4096 x 2160	59.94 / 50	MPEG-4 AVC/H.264 YCbCr 4:2:0 @ 8-bit								
			Intra	6734	940	9	36	141			
4K DCI Crop		29.97/25/24/23.98		IPB	1655	230	36	147	575		
				Intra	3373	470	18	72	282		
4K UHD Full Frame	3840 x 2160	59.94 / 50		IPB	869	120	70	280	18hr. 17min		
				Intra	6734	940	9	36	141		
4K UHD Full Frame	3840 x 2160	29.97 / 25		IPB	1656	230	36	147	575		
				Intra	3373	470	18	72	282		
Full HD	1920 x 1080	119.9 / 100		Intra	2586	360	23	94	368		
					59.94 / 50	Intra	1298	180	47	188	12 Hr. 14min
						IPB	440	60	138	9 Hr. 14min	36 Hr. 6min
		29.97 / 25		Intra	655	90	93	372	24 Hr. 16min		
					IPB	226	30	270	18 Hr. 2min	70 Hr. 27min	
IPB Light	88	12	11 Hr. 35min	46 Hr. 23min	181 Hr. 13min						

Significant control over recording file sizes is supported by the selection of either Intra or IPB modes within the MPEG-4 AVC/H.264 codec for all of the frame rates. The 4K recording data rates are high — being 940 Mbps for the highest frame rate of 59.94 fps when the Intra mode is selected. This is significantly lowered to 230 Mbps if the IPB mode is selected.

4.2 MPEG-4 HEVC/H.265 — Data Rates, Files Sizes and Recording Durations

For both the 4K DCI and 4K UHD video formats, the MPEG-4 HEVC/H.265 codec can be selected and the choice of Intra (All-I) or Inter (IPB) options is also selectable for all frame rates. Table 9 shows the associated recording data rates, file sizes and recording durations for all frame rates. 5.5K RAW is included as a reference.

TABLE 9 Data Rates, File Sizes, and Recording Durations for the 4K formats and Full HD

Video Recording	Resolution	Frame Rate (fps)	Codec	File Size (MB/min)	Data Rate (Mbps)	Recording Duration (Minutes) CFexpress Card			
						64GB	256GB	1TB	
5.5K RAW	5472 x 2886	59.94 / 50	<i>Proprietary</i>	18711	2600	3	13	50	
		29.97/25/24/23.98		12937	1800	4	18	73	
4K DCI Full Frame	4096 x 2160	59.94 / 50	MPEG-4 HEVC/H.265 YCbCr 4:2:2 @ 10-bit						
			Intra	7164	1000	9	36	141	
4K DCI Crop		29.97/25/24/23.98		IPB	2443	340	36	147	575
				Intra	3373	470	18	72	282
4K UHD Full Frame	3840 x 2160	59.94 / 50		Intra	7164	1000	9	36	141
				IPB	2443	340	36	147	575
		29.97 / 25		Intra	3373	470	18	72	282
				IPB	1227	170	70	280	18hr. 17min
Full HD	1920 x 1080	119.9 / 100		Intra	3373	470	23	94	368
		59.94 / 50		Intra	1227	170	47	188	12 Hr. 14min
				IPB	655	90	138	9 Hr. 14min	36 Hr. 6min
		29.97 / 25		Intra	977	135	93	372	24 Hr. 16min
				IPB	333	45	270	18 Hr. 2min	70 Hr. 27min
IPB Light	131		18	11 Hr. 35min	46 Hr. 23min	181 Hr. 13min			

Again, control over recording file sizes is supported by the selection of either Intra or Long GOP modes within the MPEG-4 HEVC/H.265 codec for all of the frame rates. The recording data rates are higher than for MPEG-4 AVC/H.264 — being 1000 Mbps for the highest frame rate of 59.94 fps when the Intra mode is selected. This is lowered to 340 Mbps if the IPB mode is selected.

4.3 Video Format Details for Recording of 4K and Full HD

TABLE 10 Video Format Details for the MPEG-4/H.265 and MPEG-4/H.264 Codecs

4K Video Recording	Choice of Codec		Color Sampling	Color Matrix	Bit Depth	Video Signal Record Range (Digital Code)	Frame Rate (fps)	File Format	Audio	HDMI Output
	MPEG4 H.264	HEVC H.265								
<ul style="list-style-type: none"> • 4K DCI Full Frame • 4K UHD Full Frame • 4K DCI Crop • Full HD 										
Canon Log ON		○	YCbCr 422	BT.2020 BT.709	10	128 – 1016	59.94P / 50P 29.97 / 25 / 24 / 23.97	MP4	Linear PCM or AAC	YCbCr 422 10-bit* BT.709 / BT.2020 Range: 128 – 1016
Canon Log OFF	○		YCbCr 420	BT.709	8	0 – 255	59.94P / 50P 29.97 / 25			YCbCr 420 8-bit* BT.709 Range: 32 – 254

* Note: When output is connected to a device without full range support the code range is 174 – 934

5.0 VIDEO CONNECTIVITY OF THE EOS-1D X MARK III

The EOS-1D X Mark III is well endowed with critical connectivity that supports a range of single operator style shooting. Prominent among these is the ability to connect the uncompressed 4K video to an external recorder or to an on-set 4K reference display using a single cable — via HDMI 2.0 interface. This important interface feature allows the user to check image quality on a large, high quality display while also critically checking focus during shooting.

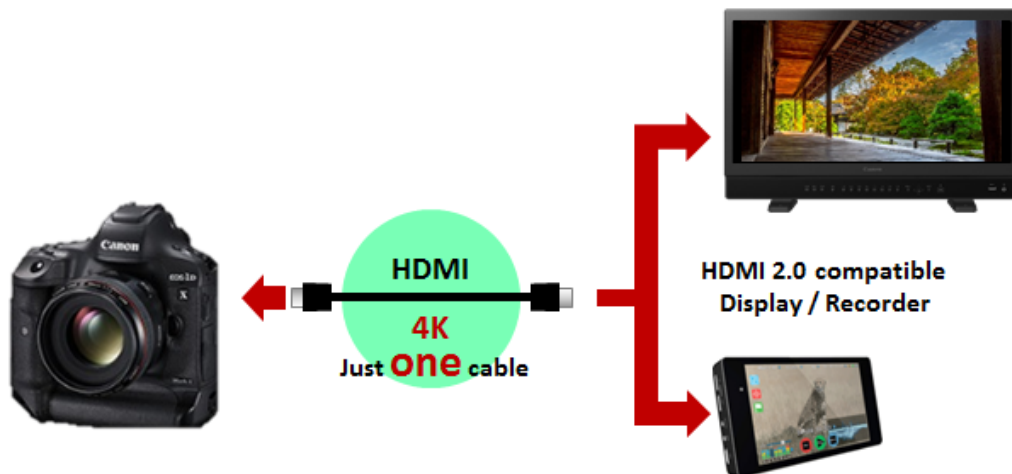


Figure 11 The single cable interface between the HDMI connector and external devices supports transfer of all 4K formats

The HDMI interface supports transfer of uncompressed 4K DCI/UHD YCbCr 4:2:2 @ 10-bit, uncompressed 4K DCI/UHD YCbCr 4:2:0 @ 8-bit or uncompressed RGB @ 8-bit to external recorders or displays. In terms of color space, the interface supports BT.2020, BT.709 or BT.601. Content in the

particular output format selected in the camera will be displayed on the external display or recorder connected to the HDMI interface (what is displayed may vary, depending upon the specifications of the external device).

6.0 WORKFLOW FOR THE EOS-1D X MARK III VIDEO SHOOTING

6.1 Options for the EOS-1D X Mark III Stand-alone Video Production

While the 5.5K RAW recording ensures the greatest flexibilities in postproduction image manipulation (adjustments to contrast, low-light detail, color and tonal reproduction), the alternative on-board recording of YCbCr 4:2:2 @ 10-bit with Canon Log (using the MPEG-4 HEVC codec) also delivers very high image quality — with 12-stops of dynamic range and a choice of wide color gamut BT.2020. Figure 12 suggests just one workflow example where the 5.5K RAW is the master recording and MP4 is the simultaneous recording. Uncompressed 4K (DCI or UHD) is another recording option using the HDMI interface to an external recorder. Within the Canon shooting environment, NLE Plugins are available from both Avid® and Apple®, and the Canon DPP is another option for data development. Downstream, Canon will also enable the Cinema EOS CRD (Cinema RAW Development software) as yet another development tool.

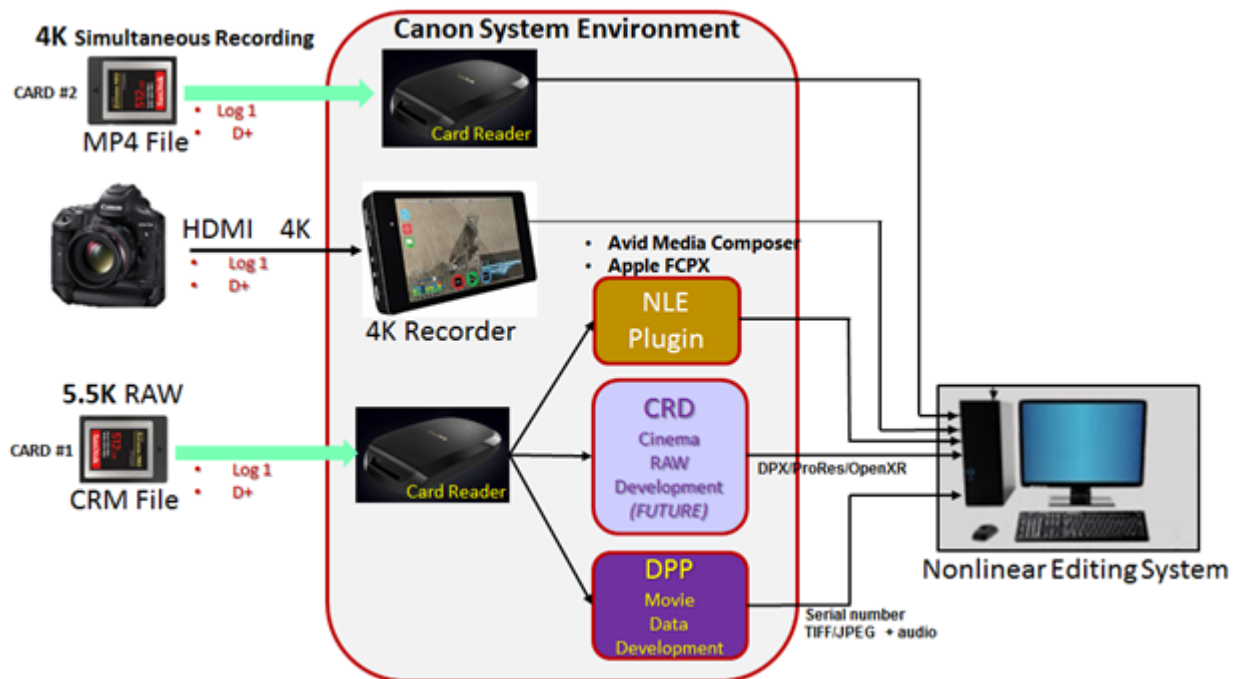


Figure 12 Typical video workflow for EOS-1D X Mark III

6.2 Workflow for Acquisition System that includes the EOS-1D X Mark III and Cinema EOS Cameras

It is not uncommon today to see professional DSLR and Mirrorless cameras integrated into multi-camera productions for high-end episodic television or movie productions — as B and C cameras where their relative compactness can offer important shooting flexibilities. The 5.5K RAW video capability of the EOS-1D X Mark III offers image quality that will readily integrate into professional cinema originations. Figure 13 suggests one of many possibilities — here the EOS-1D X Mark III is working with a Cinema EOS C200 camera. Both use similar algorithms to reduce the storage load on their respective memory cards, but there are small differences between Cinema RAW Light of

the EOS C200 or EOS C500 Mark II, and the RAW video of the EOS-1D X Mark III. Contemporary NLE systems in postproduction can easily match the modest tonal differences between the two camera types.

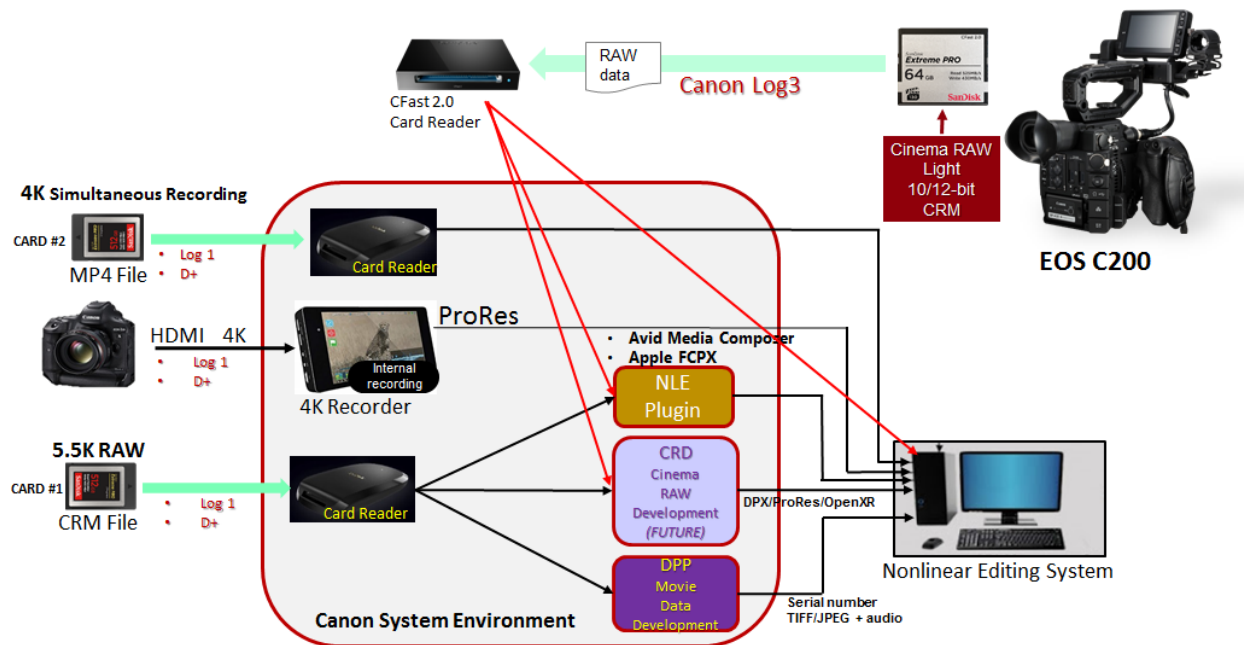


Figure 13 Workflow when the EOS-1D X Mark III is part of a multi-camera Cinema RAW/Cinema RAW Light system

7.0 SUMMARY

The EOS-1D X Mark III is a digital imaging gem. For both still photography and digital motion imaging, it embodies multiple advances within all facets of what it takes to produce an unparalleled DSLR. It takes still photography beyond the impressive capabilities of its predecessor, the EOS-1D X Mark II, on a number of fronts. But, it is on the video front that the EOS-1D X Mark III moves very decisively beyond the modest 4K / HD capabilities of that camera. Because of the breadth and sophistication of the 1D X Mark III's video capabilities, this white paper focused exclusively on the extraordinary advances in video recording embodied in this DSLR.

Full-frame 5.5K RAW (up to 60 fps at a 12-bit depth) is a video capability that thrusts the EOS-1D X Mark III into the highly sophisticated labyrinth of contemporary high-end motion imaging cameras. It offers the established professional still photographer a powerful capability to extend their professional services into the many constantly evolving domains of serious modern-day video capture. This could encompass ancillary acquisition in moviemaking, episodic television production or television and video commercial production — as well as a host of independent lower budget high-quality productions.

The choice of 4K DCI or 4K UHD recording was described in some detail because of the broad-ranging flexibilities that are offered. The MPEG-4 AVC /H.264 recording codec offers the efficiency of YCbCr 4:2:0 @ 8-bit recording — a standard long-established worldwide — with extraordinary long-duration recording capabilities that are important to many forms of web-production, broadcast newsgathering and documentary origination.

The alternative MPEG-4 HEVC/H.265 codec with Canon Log thrusts the video capabilities squarely into the realm of high-end YCbCr 4:2:2 @ 10-bit production — a standard accepted worldwide by major broadcast networks and high-end independent production facilities.

HDTV has not been forgotten. This is still the most widespread video production format across the globe, despite the slow and steady penetration of 4K UHD. The EOS-1D X Mark III offers a similar choice between the H.264 and H.265 codecs, which eases the camera into basically any of today's HD production systems. The ability to record very high quality 120/100 fps HD — capitalizing on the wide horizontal viewing angle of the full frame image sensor — advances the camera's capabilities into many forms of sports coverage (for slow motion), high-end documentaries, as well as special effects in movie and commercial productions.

In video terms, the EOS-1D X Mark III is truly a "Camera for all Seasons."

8.0 REFERENCES

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