Design Considerations for Direct-to-Disk Recording Systems & Workflow

By: Terry Cullen, CEO and Founder, 1 Beyond, Inc.
May 7, 2007

Based on the Design of the 1 Beyond HD D2D-Max™

As High Definition video gains popularity, both as an upgrade from standard definition and as an alternative to film, there is a natural quest to increase quality. One of the biggest problems with HD quality is tape compression. Since quality loss occurs in the original video acquisition, in a pure video workflow, the original quality is never seen and can never be accurately recreated.

The main **goal of Direct-to-Disk Recording** is to eliminate tape compression thereby yielding the **highest possible quality**. Capturing the original pristine quality is not only important to producers replacing film (which has no color or resolution loss), but it is also extremely important for green screen VFX. Of course, increased quality is appealing to producers at all levels if it can be made cost effective. Other significant goals of Direct-to-Disk recording include:

- True camera direct to instant edit workflow
- Longer HD recording times
- Ability to record formats like 2K which can not be captured on tape
- Highest quality video acquisition from higher compression cameras e.g. HDV cameras with HD-SDI

Background:

It is physically impossible to capture full-resolution uncompressed HD to tape. Uncompressed HD (4:4:4 10-bit 1080) bit rates are almost 2Gb/s. Today's state-of-the-art tape decks (>$150K) can only record 25% of the data in 4:4:4 10 bit 1080 video stream. They do not even attempt 2K at any compression. In-camera recorders are a small fraction of that (see table below). What happens to the other 75% or more of the data? It is LOST through resolution reduction sometimes referred to with phrases like "advanced digital pre-filtering and dynamic bit-allocation" in addition to final compression. The table below shows that only 2-25% of video data is retained on tape. When a tape is played, the missing data is approximated, but it is impossible to accurately re-create it.

The chart below shows various HD video formats, claimed compression ratios and actual data loss on tape.

HD Tape vs. disk data	Resolution Color Y	Color Depth	Color Info	Recorded Data Mb/s	Compression claimed	Comp. Type	% Data Retained
D2D-Max	**1920x1080**	**10 bit**	**4:4:4**	**1864**	**None**	**None**	**100.0%**
HDCAM SR	1920x1080	10 bit	4:4:4	440	4.0 to 1	MPEG4	**23.6%**
D5	1920x1080	10 bit	4:2:2	355	3.5 to 1	DCT	**19.0%**
HDCAM	1440x1080	8 bit	3:1:1	144	4.3 to 1	DCT	**7.7%**
DVC Pro HD	1280x1080	8 bit	4:2:2	100	6.7 to 1	DCT	**5.4%**
HDV	1440x1080	8 bit	4:2:0	25	50 to 1	MPEG2	**1.3%**

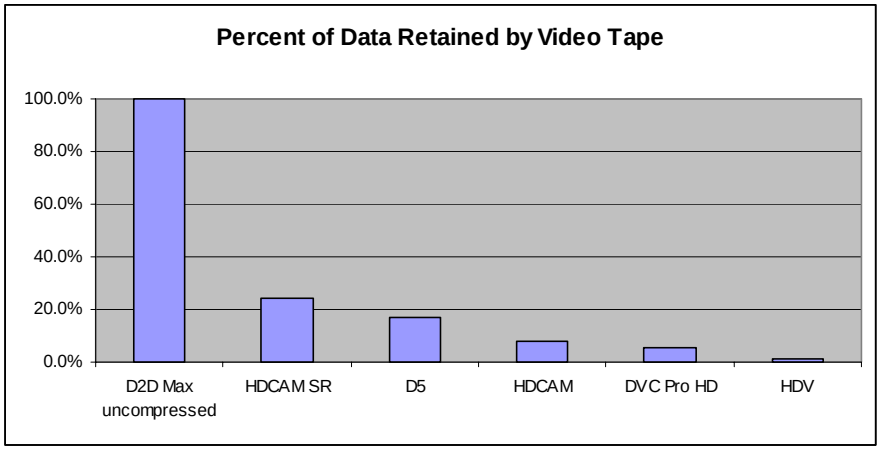
Note 1: The data in the above table is not readily available and is largely inconsistent in publications. It is compiled from the best sources available to the author - nowhere is it in one place. The point is not to argue details but realize the significant amount of data loss.
Note 2: If a camera has only single link HD-SDI, the max video data rate is 1240 Mb/s due to U V information sub-sampled at 960 instead of 1920.

How is this high compression even possible? Various compression schemes have been devised to reduce data to a tape acceptable data rate. Most, if not all of these schemes are designed to take advantage of the weak points of the human eye which is much more sensitive to brightness than actual color. Engineers therefore have cleverly reduced color information that to which the eye is less sensitive. It is interesting to note however that everyone's eyes are different and, the computer's "eye" does not have these weaknesses. For example when a computer is trying to follow very subtle green screen edges, not having the full color and resolution information makes this task extremely difficult and prevents the best results.

People promoting various compression types offer examples of video, usually favoring their compression technique. However at the high-end, people point to the beauty and dynamic range of film. Is this because even though the human eye has weaknesses, film has zero compression or color loss? Somehow the fact that film has no reduced resolution or color information is usually very appealing. Therefore, if we are to get as close as possible to the "film" look, video too would ideally have no missing information.

Design Requirements of Uncompressed HD Capture Systems:

- **Quality:** As can be seen in the Background introduction, quality is clearly increased as the compression is reduced. At the time of the 1 Beyond HD D2D-Max design, Direct-to-Disk recorders at a reasonable price range were not able to record without compression of their own. They were simply replacing one compression with another purportedly better. Avoiding the endless arguments of which compression scheme is best, it is hard to argue the fact that the ultimate quality is NO compression. This therefore became the first goal – uncompressed video. Another benefit of dual link uncompressed disk recording is that there is currently no video tape capable of 2K recording. High end cameras e.g. the Arriflex D-20 are capable of 2K and combined with their anamorphic lenses (used in film) can produce wider video format ratios with extreme clarity.



- **Reliability:** Uncompressed HD recording requires disk data rates from 150 to over 200 MB/s depending on size and frame rate. This is an aggressive goal that usually brings the necessity of many disks striped at RAID 0. It is a risky situation because the more disks the higher the probability of failure and a single disk failure means all video is lost. Of course, this is unacceptable or at least undesirable in most cases. The first protection step up is RAID 3 or 5 that allows for a disk failure but leaves the RAID array vulnerable where a second failure means all video is lost. The ultimate is RAID 6 where a disk failure simply means a protection reduction to a RAID 3 equivalent and the data is still protected. This allows for shooting or editing to continue under full protection. RAID 6 therefore becomes the second goal.

- **Cost:** There have been uncompressed Direct-to-Disk recorders for the high-end but their costs have been out of reach of the majority of the market. The third goal was to design a system with the above quality and reliability yet to keep the cost under $20K. In addition to the obvious benefit of more reasonable cost, this extends this quality breakthrough to the low end HDV market. Many of the new HDV cameras have excellent 3 chip front-ends, changeable lenses and HD-SDI outputs directly from the front-end of the camera. With uncompressed disk recording, you get uncompressed video from an HDV camera - completely eliminating the MPEG problems of reduced color information and broken edges due to movement.

- **Useable Workflow:** The final goal is to make a system that is supported in a useable or practical workflow. Is the data directly useable or is the only access by playing back the video and re-recording it? Ideally the video captured should be ready to go directly to the next step in the workflow. This usually means on-line or off-line editing or possibly DI. How is the data handed off to the next step? Is it possible to keep recording while the previously recorded video enters the workflow e.g. editing? There are five considerations:
    - Is the recorded data in a useable editing or DI format depending on the workflow?
    - Is there a way to remove the data from the recorder and begin using it while there is additional data being recorded e.g. a compatible disk unit for the editing station, PC or Mac that will accept the recorded video directly for immediate use?
    - How is the video backed up? Ideally the data is backed up early in the cycle so there is no chance of losing valuable footage.
    - Is the recorder itself Multi-Function? Can it be used directly without changing disks to perform full resolution HD editing thereby making it even more cost effective?
    - Is the recorder compact and portable and simple to use?

Conclusions:

The resulting 1 Beyond HD D2D-Max designs include the following specifications and system choices:

- **Choice of Formats:** The 1 Beyond HD D2D-Max records virtually all HD formats uncompressed including:
    - Single Link 4:2:2 and Dual Link 4:4:4 HD-SDI (commonly known as Sony HDCAM SR or Thompson Viper Format)
    - 4:4:4:4, 2K HSDL
    - Full bandwidth 4:4:4 RGB at 10-bits (12-bit capable) for 1080i, 1080p, and 720p formats
    - Native uncompressed DPX, Cineon, TGA, TIFF, BMP, YUV, AVI and QuickTime files

  It also converts live between 4:4:4 and 4:2:2 formats for Single Link HD-SDI monitor and backup recorder outputs and has 4:2:2 machine control.

- **Multi-Function for Flexibility:** The 1 Beyond HD D2D-Max systems enables a genuine instant camera to edit workflow, allowing users to instantaneously switch from capture to edit mode, thereby totally by-passing the time consuming process of file transfers or video ingest – a particularly useful tool for example to cut and project dailies. Back in the truck or hotel, users can simply plug in a larger computer monitor and the capture system instantly becomes a full HD editing system. 1 Beyond offers a complete complementary workflow product line including the 1 Beyond HD OctoFlex 8-processor system (rack, tower or portable) and the IntelliRaid mini-drive that will connect directly to any Mac or PC NLE via a standard SCSI connection. All of these products have interchangeable compatible disk bays.

- **Choice of Systems:** The 1 Beyond HD D2D-Max is portable but there are two additional system configurations depending on the environment and application:
    - A portable 4U rack mount case with touch screen operation and an optional travel rack case
    - A self-contained ruggedized mobile unit with built-in large LCD screen, fold down keyboard with touchpad which has internal and external storage options
    - A shock mounted 6U system with built-in removable HD storage, a pull-out combination LCD screen with keyboard and touchpad.

This White Paper is a summary document. For additional information,
contact 1 Beyond at 877-One Beyond or visit www.1Beyond.com