1 Beyond White Paper:

Design Considerations for HD Editing / Compositing Workstations

Based on the design of 1 Beyond's HD Pro Workstation

By: Terry Cullen

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I. Background:

The design considerations for High Definition HD editing and compositing workstations are entirely different from systems working with less demanding formats. For example, the data rate increase from uncompressed SD to HD can be almost an order of magnitude. Compared to the DV format, uncompressed HD requires a *46 times increase* in data rate and processing. This requirement impacts almost every subsystem of the computer and presents several design challenges.

However, there are other less obvious challenges and design differences that have been encountered. Some are purely technical, as would be expected, but a surprising number are based on feedback from users who have been early adopters of this new technology. This paper will explore these differences and how the new **1 Beyond HD Pro**™ workstation design has met these challenges and introduced some unique solutions that are now available.

II. The problem summary list:

We polled both our customers and early adopters of High Definition editing and compositing systems to determine what problems the ideal system design would solve. Here is the list of problems they typically reported:

- ? **Cost of system and support**
- ? **Proprietary systems**
- ? **Storage cost and size**
- ? **Need highest quality - uncompressed video**
- ? **Ergonomics – noise, heat, space**
- ? **Upgradeability now and in the future**
- ? **Professional stable editing interface**
- ? **Integrated graphics and editing**
- ? **Integrated with full product line**
- ? **System stability**

Following is a discussion of exactly what these problems are and how they can be solved.

III. Basic Architecture:

There are three basic approaches to handle the extraordinary data throughput and processing requirements of HD: dedicated hardware, general purpose computers and a third that can be used with either of the first two, video compression. Three years ago, when the efforts to develop workstations for HD were started (including 1 Beyond's), it was not clear which approach would be the winner. Indeed the conservative approach was to choose dedicated hardware because it was not clear that Moore's Law would prevail and allow the general purpose computer to become fast enough to handle such speeds. Certainly at the time they could not. An even more conservative

route was to choose a combination of dedicated hardware and video compression. This is even more guaranteed to work but with quality drawbacks. Each approach also has other pros and cons.

a. *Dedicated Hardware:*

Looking back at history, the older video editing systems used dedicated hardware starting over 20 years ago. The choice was very simple back then, because general purpose computers were no where near able to handle even standard definition video. Now facing the challenge of High Definition video, there is a choice. The dedicated hardware approach works but it has its pros and cons.

1. Pros:

The pro for the manufacturer is that buyers are locked into your proprietary hardware and must purchase all systems, options and upgrades from you and they must pay whatever you charge for these items and support.

2. Cons:

The con is since hardware choices need to be committed at design time, 12 to 18 months in advance of being released; when it is finally useable it is already behind the times. You run the risk of early obsolescence. You have little flexibility if the market requirements change. Also, if computers do become fast enough to do the job, the dedicated hardware manufacturer faces serious competitive pressure from cost reductions they are not able to follow.

b. *General Purpose Computers:*

The approach of using general purpose computers is more flexible and less expensive but there are also pros and cons.

1. Pros:

The pro is that the design is completely flexible. Major updates can be made at any time before or after initial release. Major updates can be continually issued from your web site at minimal cost. You can be significantly more competitive in pricing and generally the support costs are minimized. First, because there is no extra hardware that can break and secondly customers and their IT staffs already understand and feel comfortable with the PC which is the major component of the system.

2. Cons:

Three years ago, the con was that there was a huge risk. If general purpose computers did not become fast enough, you would be left with no solution.

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c. *Video Compression:*

The approach of using video compression is the easiest way to deal with the data rate problem. An example of the combination of general purpose computers and compression is consumer editing packages. If you increase the compression enough, you can process video with any computer. An example of dedicated hardware and compression at the high-end is from the 1980's; high-end video editing systems used a compression called MJPeg. Indeed this is the route that at least one high-end manufacturer has taken again today. But there are pros and cons.

1. Pros:

The pro is that with video compression, the difficulties of dealing with high data rate requirements are greatly reduced and disks can be smaller. This is sometimes considered off-line. There are markets however where this reduced quality is good enough.

2. Cons:

The obvious con is the loss of video quality. Manufacturers who have taken this route will come up with phrases like "virtually lossless" or "there's no detectable difference", like they did in the 1990's when lossless digital editing was introduced. Unfortunately, if you want the highest quality, at best you end up with the inefficiencies and risks of editing off-line. In off-line, you run the risk of missing some subtle problems. When these are detected in the finish it is often too expensive to go back and compromises are made.

d. *1 Beyond HD Pro:*

It is now clear that Moore's Law has again prevailed and computer development at the high-end has met the challenge of the data rate requirements necessary for processing uncompressed HD.

The **1 Beyond HD Pro** uses this open system, general purpose computer approach. It is therefore much more cost-effective and has the future flexibility to add new capabilities just by adding new software. Perhaps most importantly, it works in the highest possible quality, 10 bit uncompressed HD. There's no substitute for the quality and efficiencies of **HD editing on-line all the time**. You may use reduced quality for creating a batch capture, cutting 50 hours of video down to 5 then going on-line to edit. However, this is much different than the problems of editing off-line.

IV. Data Rate:

The data rate increase from SD to HD can be almost an order of magnitude increase. The increase in data rate over DV is *46 times*. This requirement impacts almost every subsystem of the computer and presents several design challenges.

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a. *System Data Paths:*

The required data rates have a major effect on most parts of the system design. The data path for example during editing starts at the disk ,runs through the internal bus structure and by the time it's displayed on the computer screen, it has passed through every major path in the system. At the same time it's converted to serial and is output to the HD-SDI and SDI outputs (if the system has simultaneous down conversion) to the NTSC monitors, tape decks etc. At normal timeline playback speeds, 1080i equates to 185 MB/s moving through the system in several directions simultaneously. This is why it was not obvious three years ago that a general purpose computer could achieve these internal data path speeds.

The **1 Beyond HD Pro** uses the latest PC technology in the internal structure. It uses the wide 64 bit fast PCI-X bus and unlike consumer computers that have one PCI bus, it has three separate PCI buses. This avoids the limitations of even the fastest PCI-X buses from becoming the data path bottle neck.
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b. *Disk Speeds:*

One of the biggest challenges for the HD system designer is disk speed. The transition from SD to HD as detailed above is very significant. For disks, this is not only a challenge for data rate but it also impacts response time. These massive amounts of data are not only required to be retrieved, but they are time sensitive. Unlike almost any other computer application, video editing is unique in its requirement for constant sustained data rate combined with fast response time. The difference of a few milliseconds response is the difference between a useable system and a frame drop, a worthless system This is also combined with the requirement for completely random access. If you have a clean disk and are inputting data from a tape deck, the writing is fairly contiguous. When you edit and playback the time line which contains portions of clips in completely random order, this task is much more difficult.

The traditional approach to this problem is to use SCSI disks. SCSI disks in a raid configuration can just barely do the job, but they can do it. However as you will note in the following sections, there are many disadvantages to this approach.

c. *Disk Bus Speeds:*

The first disadvantage of traditional SCSI is disk bus design. Disk speed in a SCSI raid configuration is sufficient for HD if you use enough disks but you can not have too many disks on a given bus. The speed curve goes up with the number of spindles (disks) but with SCSI you reach bus bottleneck point. The SCSI bus design allows as many as 16 drives on the same SCSI bus. This bus has a high momentary bus speed (which is what you see quoted, 320 MB/s), but this is not sustained for even a small amount of time. To make matters worse, because the bus design allows up to 16 drives on a single bus, as the number of disks increases, you reach a peak and then the sustained data rate actually decreases due to too much bus traffic. Therefore the maximum sustained data rate for SCSI is typically over 200 MB/s. Again this will

sustain a single stream of HD which requires 185 MB/s, but there is not much head room.

See below for 1 Beyond's solution to this problem which more than doubles this sustained throughput.

V. Storage Size:

The other major disadvantage of SCSI disks is available storage size. Given the fact that HD can require as much as 10 GB/min, you can see the problem of limited storage size. The typical SCSI storage configuration is 7 drives per bus with 2 buses for a total of 14 disks. This means you are limited to 2 TBs of storage. This limitation brings us back to 1994 when we had to do SD projects in sections due to storage limitations. Worse yet, if you apply raid 3 protection 2 TBs is reduced to 1768 GBs. Allowing for temp files and other project components this leaves a little over 100 minutes of raw video storage. Editors today are spoiled because disks have become so large that when working in SD you can have the luxury of many hours of raw footage instantly at your disposal.

With 1 Beyond's unique **HotRock™ storage** (discussed below), the **1 Beyond HD Pro** system can have as much as **7.5 TBs** of internal, fast, **raid 3** protected storage.

a. 1 Beyond HotRock™ Storage:

1 Beyond HotRock™ storage (**Hot** performance / **Rock** Solid) has a unique solution to the disk speed and bus speed problems. HotRock storage has a separate bus for each disk. This eliminates the bus traffic problem and combined with the fast and separate PCI buses discussed above, yields over **400 MB/s of sustained data rate**. Roughly twice the sustained data rate of traditional SCSI disks. Some of the advantages of this storage are obvious but many are much more subtle. The discussion below elaborates on these advantages.

VI. Impact on the Editing Experience:

An important part of the editing experience is the responsiveness of the system. When an editor or artist uses an HD system for the first time, they are often surprised by the lack of system responsiveness.

a. Smooth Response:

Smooth response is very dependent on the data rate of the system. Straight playback requires 185 MB/s. When you scrub the timeline for example, you are requesting much faster data throughput than simply playback. Editors today are accustomed to virtually instant response because the data rates of typical SD systems are many times faster than the required data rate for SD. When you work on a system with barely enough data rate to play the HD timeline, there is a definite sluggishness to operations like scrubbing and searching for an edit point. To test this, try the "J K L" keys test. For those unfamiliar with the search keys, successive "L" keys move the

timeline playback faster: first twice, then four, then ten times the playback speed. The "K" key instantly stops play back and the "J" key moves the playback in reverse faster and faster. A professional editor who is used to using these keys is often disappointed with the response of an HD system.

Professional editors who have tested the **1 Beyond HD Pro** have been very pleased to find it so responsive. Again, this smooth and instant responsiveness is due to the fast internal buses combined with the unique 1 Beyond HotRock™ storage.

a. *Audio Lag:*

Audio lag is another area of frustration to a professional editor who is first trying a less responsive HD system. When searching for an edit point, an editor is often dependent on a point (word gap) in the audio. It can be very frustrating if there is even a split second audio lag when starting playback or scrubbing. Again, test this as explained above with the "J K L" keys. With the **1 Beyond HD Pro**, you can quickly find the edit point you want without having to do several iterations of "cut and play". , This may sound insignificant but it is another example of why system responsiveness can spell the difference between a pleasant, efficient editing experience and frustration. Also note that editors who have not experienced the difference of a fast system may not know what they are missing.

VII. Ergonomic Factors:

An area that is very often overlooked when considering an HD system is the ergonomics: This has not been a factor in recent times because a typical SD system does not usually encounter problems relating to noise, size or heat. Users are therefore surprised by some of the unique problems HD systems present. Consider the significant differences between SD and HD in the following areas.

a. *Noise:*

System noise has never been pleasant but it's an area that users have become accustomed to it and it is not usually very high of the list of purchasing criteria when choosing a system. There are two important noise factors to be taken into consideration with HD, the system and the disks. The systems by definition are very high powered. High power equals high heat and high heat equals fan noise. Systems design has come a long way in keeping the noise down, but whatever noise, it is minor compared to the necessary disk noise.

Unlike computers, disks are inherently noisy. If you are considering a system with several SCSI disk spinning at 10 to 15,000 RPM, you should check the noise first. Remember we are also talking about 10 to 40+ times more disks over SD. Many early adaptors of HD have reported the noise so deafening, the only way to hear the project they are editing is to wear headphones. Also remember that **noise is a major fatigue factor.**

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The **1 Beyond HD Pro** system has greatly reduced this problem in several ways.

1. Cabinet design:

First, the **1 Beyond HD Pro** system cabinet is much heavier than the typical computer cabinet. It is literally designed with very heavy gauge aluminum and steel. This offers very effective sound containment and sound deadening. The system is also available in a smaller cabinet if you are using remote storage like 1 Beyond's Harmony Shared HD SAN.

2. HotRock™ Storage:

The unique 1 Beyond HotRock™ storage has several noise advantages. The density is approximately twice that of SCSI. Therefore there is almost half the number of disks per TB and they are running half the RPM (yet giving twice the data rate). This yields a significant sound reduction.

3. Ultimate in Quiet Operation:

Even with the low noise design of the **1 Beyond HD Pro**, the ultimate in noise and fatigue reduction is to have no equipment in the editing room. With **1 Beyond's Silent Partner™** option, the disk arrays and system can be kept quietly in a remote location. Only the necessary (and quiet) devices are on the desktop, including single or dual monitors, wireless keyboard and optical mouse, analog and/or digital speakers, SD / HD NTSC monitor and DVD / CD burner / player. Other remote devices for the workspace or equipment room are also available.

- **?** **Remote System** – With **Silent Partner™,** the **1 Beyond HD Pro** system can be located in an adjacent room or using the supplied electronics and cabling, at distances up to 60 feet away.

- **?** **Rack mounted** - The System can also be rack mounted in an equipment room with optional 19" Rack Rail Kit. It is also available in a smaller rack mount case when using external storage like 1 Beyond's Harmony™ Shared HD SAN.

b. Heat:

The heat generated by the combination of a powerful system and arrays of SCSI disks is significant. It can easily over heat a small edit suite. Try touching a SCSI drive that has been spinning for an hour. It is dangerously hot to the touch. This added heat can be very undesirable if it raises the normal temperature of the edit suite by 10 to 20 degrees!

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The **1 Beyond HD Pro** with HotRock storage is actually cool. Hold your hand behind it and feel the exhaust fan. Half the number of disks spinning at half the speed is a significant heat reduction. Also 1 Beyond's Silent Partner™ option can help.

c. Physical Size:

The physical size of an HD system with up to 7.5 TBs of storage is significant. This can easily be a full rack of equipment. The **1 Beyond HD Pro** with this amount of storage is contained in one attractive cabinet. In a crowed office or editing suite this can be a factor to consider. The 1 Beyond's HD Pro Silent Partner™ option can help here as well.

d. Integration:

If an HD system configuration consists of several cabinets to house system, hardware and disks, this can lead to an undesirable, collection of cabinets, cables and power cords. This is a setup, support and even an aesthetic consideration. The **1 Beyond HD Pro** has solved this problem by keeping all components, power cords and cables self contained. It comes turnkey so you can just set it up as you would a normal computer. From an aesthetic point of view, it has a very clean and self contained design. It even has two lockable doors that hide all of the front components and removable disks. There are no cables and power cords interconnecting multiple cabinets.

VIII. Financial:

a. Cost of system:

The cost of the system speaks for itself. The **1 Beyond HD Pro** fully configured can save considerable money over traditional HD systems. This is due to the basic approach of using the general purpose computer to provide the HD solution.

b. Cost of Storage:

The unique 1 Beyond HotRock™ storage in addition to its high performance is the most cost effective in the industry. Compare a complete cost of $3.90/GB including cabinet, power and cables to other storage solutions. Also consider this storage is fully raid 3 protected, fast, externally removable and quiet.

c. Upgrade Path:

A major cost factor in video systems is the ability to upgrade. Do I have to throw out what I have and start over? 1 Beyond systems by design have upgrade possibilities on several levels:
- On a configuration level, you can purchase just the amount of storage you require at the time and upgrade later. For example you can get 2.5 TBs of HotRock storage and upgrade later to 5 TBs or even 7.5 TBs.
- You can start with 500 GBs of Digital Video Transport™ near-line storage and upgrade later to 1.5 TBs.

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? On the systems level, 1 Beyond's primary design criteria is on Open Architecture and World Standards. Therefore since we have built the **1 Beyond HD Pro** on the industry PC standard, you are never locked out of new upgrade possibilities in hardware or software.

? On a format level, **1 Beyond** pioneered the concept of a system that could upgrade from DV to SD to HD with its Convertible™ system.

? 1 Beyond has a unique trade-in policy. You can purchase the system you need today with the card you need and trade-in later. For example, you can purchase a system now that is designed for HD and only buy the DV or SD card. In the future you can trade-in this card and upgrade to HD.

d. Cost of HD Deck:

1 Beyond brought the price of high quality 10-bit uncompressed HD editing down to the former price of off-line editing, but this left the problem of requiring a $65K HD Deck. Now with the optional **1 Beyond Digital Video Transport™** near-line storage, this cost is eliminated as well as adding several other valuable features:

? Loading HD footage without an HD Deck using a 1 Beyond Video Transfer Center.

? Backing up and Archiving HD Projects.

? Encrypting and sending HD rough cuts from a remote shoot to be viewed at the home studio.

? Encrypting and sending HD projects between production locations in the same building or around the world.

? Transferring the completed project back to master tapes for archiving and distribution by encrypting it and sending it to a 1 Beyond Video Transfer Center

? Enables use of a playback only deck for production convenience and the Digital Video Transport option to transfer the finished project back to tape. A playback only deck can be less than a third the price of one that records.

IX. Editing Interface - Premiere Pro:

One of the major decisions in designing an editing system is the editing software. For the HD market, it not only has to meet the hardware / software throughput requirements of HD, it has to be a professional interface which will satisfy the most demanding editor in terms of function, ease and efficiency of use, scalability, maturity and integration with other programs.

1 Beyond's policy of open systems and world standards allows us to choose the best. It also allows us to add applications and even have multiple solutions for different customer requirements. Customers and potential customers have told us this is becoming a more important criterion in their

buying decision. They feel the open system and world standards policy is a very important benefit. Some are even saying it's becoming a requirement. They do not want to be locked in if something better comes along. You are not forced to use the one and only solution developed by our company. This applies to hardware e.g. video capture cards as well as software. You are making a very large commitment and to the extent that there can be flexibility and options in the future, it's reassuring and makes the commitment easier.

At this point in time there are very few software applications that fit all of these criteria. The one that we feel fits best and will continue to be a standard in the industry is Adobe's Premiere Pro.

If you have seen Premiere versions 1 though 6.5, they do not do Premiere Pro justice. Premiere Pro is a complete rewrite (a three year effort) and it's so different from the old Premiere that people have said it should not have been named Premiere. The problem is Premiere has become a standard for at least part of the industry having more users than any other editing application. Now with this new version, they are also addressing the top professional market and are in the small group with the top contenders.

Consider the following short list of new features.

a. *New Video Features:*

- ? Nested Sequences
- ? All filters and functions key-frameable
- ? Virtually unlimited Video tracks
- ? Transitions and filters on any track
- ? Scaleable with identical interface with DV, SD or HD
- ? Keyboard can be Avid or Final Cut Pro compatible

b. *New Audio Features:*

- ? Sub-frame audio editing down to $1 / 96,000^{th}$ of a second.
- ? Editing 5.1 Dolby in either analog, SPDIF or AES / EBU digital
- ? A complete selection of integrated audio correction and sweetening filters
- ? Virtually unlimited audio tracks

c. *Tight Graphics Integration:*

- ? Many After Effects built into Premiere
- ? Key-frame compatibility with After Effects
- ? Same user interface as After Effects and Photoshop
- ? Timelines can be moved from AE to Premiere and vice versa

d. *Editing Standards:*

- ? More plug-ins and compatible with AE plug-ins
- ? Different hardware options for HD video cards
- ? Based on PC / Windows standard which is 97% of the market

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In this brief description, we can not do this new application justice. If you have not had a chance to see the new Premiere Pro, please call and we will send you a DVD introducing its capabilities and demonstrating its integration with Audition for audio editing, Encore for DVD authoring, After Effects for video effects and Photoshop for stills.

X. System Stability:

1 Beyond has been responsive to issues of system stability throughout its 8+ years of existence and has developed a reputation of designing and building solid reliable systems. Now we are introducing what we believe will become another industry requirement.

? **1 Beyond Bullet Proof**™ Protection: for an added level of confidence that the most prevalent video system problems are being monitored.

This option includes protective redundancy hardware and system scanning software developed by **1 Beyond**. On system start or whenever invoked, **1 Beyond Bullet Proof**™' protection diagnostic software scans the system to predict and avoid some of the most common video-related system failures. In the eight years **1 Beyond** has been building and supporting video systems, we have learned the most common system problems (user, software and hardware) and how they can be predicted and often avoided.

? **User Problems:** When someone calls for help, in the majority of cases we use the same list of questions to locate and solve the problem. Now we have taken this knowledge to the next level, we've automated it and made it pro-active. We monitor these potential problem areas and avoid them through automatic system scanning software.

? **Hardware Problems:** The most troublesome hardware problems in terms of down time are covered by added redundant hardware. Bullet Proof protection also avoids the problem of system disk failure by adding automatic system disk mirroring.

? **Automatic Diagnostic Download:** There is also a unique option that if a critical situation arises, the system can automatically contact the 1 Beyond support team with diagnostic information. This saves considerable time by sending exactly the information needed to analyze and again avoid potential problems.

? **Segmented Raid 3:** Disk failure is so potentially disruptive, we have added another stability improvement feature to 1 Beyond's HotRock storage, segmented raid 3. With this feature there can be up to 6 disk failures in 7.5 TBs without losing data.

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XI. Integrated with full Product Line:

The market today is demanding more and more integration. A customer does not want to buy individual components and have to take responsibility or time for integration.

1 Beyond's HD Pro is not a stand alone product. It has a complete supporting product line for expansion now and in the future including,

- **1 Beyond's Harmony**™ SAN for sharing data and projects among several workstations,
- **1 Beyond's Redline Render™ Farm** for increased rendering efficiency and productivity increase,
- **1 Beyond's High Performance Laptops** for compatible field off-line editing,
- **1 Beyond's HD Pro Mobile™** for compatible field on-line editing,
- **1 Beyond's AirBrush™** system for On-Air graphics painting

XII. Summary:

In summary we have listened to our customers and we have polled early adopters of High Definition editing and compositing systems to determine what problems the ideal system design would solve. The problem summary list to be solved included:

- ? **Cost**
- ? **Proprietary Systems**
- ? **Storage cost and size**
- ? **Highest Quality - uncompressed video**
- ? **Ergonomics – Noise, Heat, Space**
- ? **Upgradeability**
- ? **Professional Stable Editing Interface**
- ? **Integrated Graphics and Editing**
- ? **Integrated with full product line**
- ? **System Stability**

We have responded to this list and developed a **premium yet affordable, non-proprietary, highest video quality system** with features and options unique in the industry:

Our new **1 Beyond HD Pro line of editing and compositing workstations**.

XIII. The unique features and options include:

- ? ***1 Beyond's HotRock™ Storage:***
  HotRock™ - Hot Performance / **Rock** Solid, for the fastest (400+ MB/s), most cost effective ($3.90 / GB), fully protected (Raid 3) HD capable storage in the industry.

- ? ***1 Beyond's HD Pro system cabinet:***
  For the coolest, quietest, self contained, compact HD system yet containing up to 7.5 TBs of high performance storage.

- ? ***1 Beyond's Silent Partner™ Remote Operation:***
  For the ultimate in quiet, low fatigue, editing and compositing environments.

- ? ***1 Beyond's Digital Video Transfer™ Near-Line storage option:***
  For the elimination of HD Deck costs and other transfer, archive and backup options.

- ? **1 Beyond's Bullet Proof™ Protection:**
  For an added level of confidence that the most prevalent video system problems are being monitored while the most problematic hardware is protected by redundancy.