With the benefit of hindsight

Over the past year of producing both HD DVD and Blu-ray Disc, a number of lessons have been learned from this practical experience

One year after the HD DVD launch, it's worth taking the time to review where we are and what we've learned about the HD DVD and rival BD processes. Eclipse is in the fortunate position of having equipment in all of the major replication facilities involved in the production of HD DVD and BD.

At Eclipse, we view the HD DVD and BD processes from the perspective of the image as it moves through the process: from authoring, where the image is created; to pre-mastering, inside the replication factory – where the images are readied for glass mastering; to mastering, where the image is permanently recorded; then finally to the QC process where the replicas are checked for correctness before shipping.

Working closely with the format founders, authoring software developers and replicators during the past year has given us a unique perspective to see the many challenges encountered in the manufacture of each format. This co-operation has also allowed us to better design our tools to streamline and simplify the process for our customers.

Testing and moving images through the process are very similar between BD and HD-DVD, so for the sake of simplicity, I'll sometimes refer to them collectively as HD.

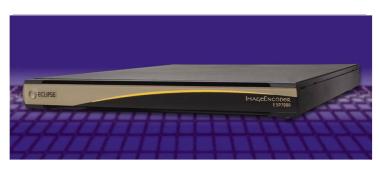## Authoring – image creation

From a replicator's perspective, the HD process starts with the output of the image from the authoring software. With a new format and fast-changing versions of software there are lots of opportunities for mistakes, especially with HD's complicated authoring. This makes it even more important to check the image before introducing it into the replication process.

Bob Edmonds,
VP Sales and Marketing,
Eclipse Data Technologies

"HD's complicated authoring makes it even more important to check the image before introducing it into the replication process"

It's no longer enough to create just the image at authoring. In addition to checksums, which have been used in the process for years, it is becoming more common for images to be created with a signature. A signature is not a tag or reference pointer to the image, but a mathematical representation of the image. Different from a checksum, the same signature can be calculated from an image at any point in the process. For example, even though there are necessary changes made as an image moves from the authored CMF (cutting master format) file structure, to an AACS encrypted image, and later to a replica, a signature calculation will always produce the same value. And since it can be calculated from the image directly, it doesn't require a connection to a metadata file.

There are tremendous benefits to adding an image signature early in the process – from disc tracking, to 'source-less' verification. Having a signature and checksum with the image from authoring ensures that the right image arrives in the factory intact.

Signatures have been in use in many DVD processes for some time, but with newer authoring software creating the signature automatically, HD will introduce many more customers to the concept.

The delivery medium for HD content is the subject of many discussions between authors and replicators. Presently, HD images are being delivered to factories via high-speed connections or on portable hard drives; however, there are several initiatives to move to some type of tape format. There is a cost advantage to tape, but the AACS encryption (done later in the process) relies on the random access afforded by hard drives. Moving to tape will add the potentially slow steps of moving the image to and from the tape. Of course we'd also all like to avoid the compatibility problems that DLT brought to our industry. As with DVD, perhaps master delivery will evolve to recordable media once suffi-cient reliability, compatibility, and capacity of high-density recordable optical media is established.

The course of the first year has given us the chance to strengthen our analysis engine by working closely with the major authoring studios and software developers. Such partnerships are essential. Developing analysis tests by using only the format specifications quickly shows that they are often incomplete, ambiguous, and subject to interpretation. Eclipse's ImageAnalysis software now provides a quick and complete check to ensure that the image is ready to move to manufacturing.

Pre-mastering – into the factory

If you compare the DVD pre-mastering process to HD, there are a couple of noteworthy changes. For copy-protected HDs, it's necessary to encrypt the image before mastering. With DVD this was done real-time during mastering. In spite of early reports that AACS copy protection would add significant complexity to the process, it is not necessarily the case. For sure, the two-day delay that it takes to get the licensing authority to sign the content certificate changes the way you must quote lead-times to your customers, but from an operator and image management stand-point, the process is fast and simple. In Eclipse's case, one program analyses the disc to detect authoring mistakes, validates the UDF files structure and signatures, adds the copy-protection, and manages keys and content certificate signing process.

One of the biggest challenges to the HD process is ensuring that images are thoroughly analysed before they continue through the process. The AACS certificate signing process does add sig-

nificant cost and time making it important to identify mistakes early. For this reason, Eclipse's development effort placed a great focus on creating a new analysis engine specific to the new formats. The experience of hundreds of titles and close partnerships with authoring software developers has helped this effort tremendously – yielding an analysis engine with more than 200 new rules for BD and HD DVD.

As has been the case since CD and DVD, verifying the image after it is copied to the mastering server is vital to ensure that the image was not corrupted as a result of an undetected error during the copy process. This process benefits from the use of image checksums created during authoring. If the image arrives in the factory with a checksum, we can calculate the checksum as we read-in the image. If it compares to the original checksum, the second read-verify pass can be skipped, saving valuable time.

Archiving – an ongoing issue

One area of the process that hasn't been completely sorted out yet is archiving. With the DVD process, images typically arrive on tape or DVD recordable media. The original source (or a copy of it) can easily be archived. In the case of HD, source images come on portable hard drives or via electronic delivery. Plants need to create an archive copy of the source, but on which medium, and at which stage of the process?

The pre-mastering process of an AACS disc sees the image in three states; the original source, the encrypted image before certificate signing, and the encrypted image after certificate signing. Which version, or versions, should be archived? The certificate signing process takes about two days and carries a substantial cost, so the archive process must preserve the signed certificate. One logical choice is to archive the encrypted, signed image. The drawback with this method is that you no longer have the original customer source should it be necessary.

A better option might be to preserve the files and certificates that are necessary to re-encrypt the source back to the same image should it become necessary to re-master the image. As the various options are being weighed, the best we can do for now is offer maximum flexibility to allow our customers to archive at any point in the process.

Once a factory decides which image to archive, the question becomes which media should be used? Most agree that portable hard drives are not a good option for archiving. There are proponents of using recordable media. However, aside from the fact that a full dual-layer BD image won't fit on a BD-R disc, the long-term stability of HD recordable media isn't yet known. Although no one wants to get saddled with future compatibility problems, tape may be a good alternative for archiving. From a cost standpoint, some tape formats are attractive.
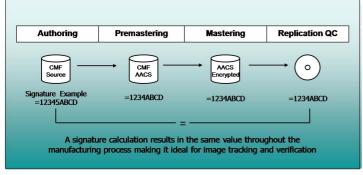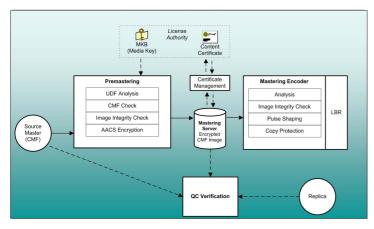
Mastering – permanently recording the image

Because the image cannot be changed once it's mastered, the encoding process is a good opportunity to check again for mistakes. Modern formatters, like Eclipse's ESP7000, analyse the image on-the-fly during mastering. Mastering should not proceed when severe, unfixable errors are detected.

It's also essential to verify that the image is still intact by validating the checksums created earlier in the process. If a file transfer error corrupts even one bit of the image, it's detected during this important step. At Eclipse we have seen examples of replicas created with data from two images – mixed up because of hard drive corruption. A quick check of the checksum ensures that the image is still correct as you master it.

QC – the last chance

Replication QC verification remains an important last-check process for the HD and BD, as it was for DVD. It is a chance to check that the replica is an accurate representation of the authored image and that the correct image has been replicated.

In the past, it was common to compare replicas directly to the source image or the pre-mastered image held on the mastering server. While still possible, HD plants prefer to utilize server bandwidth and capacity for the high HD mastering requirements, rather than for verification. A better process, provided by newer verification software, is to compare the replica to the image signature created when the image entered the process. And, although the signature is only 16 bytes, it can be used to completely verify a replica. The verification process will fail if the replica is not bit-for-bit the same as the source image.

Newer verification and analysis software also provides better layer matching. It quickly checks whether dual-layer images belong together, helping replicators verify that layers are not mismatched. All of these enhancements are aimed at giving the replicator a safe, flexible, and efficient process.

In conclusion

As an industry, we have accomplished a great deal during this first year of HD production. Solid processes are place and discs are shipping.

Replicators just now coming into HD DVD or BD manufacturing have the benefit of the year-long learning process that has helped forge our tools and better define the processes of moving images from authoring through replication.

Of course, as with earlier formats, there will continue to be new pitfalls and new problems that will need to be solved. But this is how the processes will continue to evolve and improve.

| Authoring | Premastering | Mastering | Replication QC |

CMF Source → CMF AACS → AACS Encrypted → O

Signature Example
=12345ABCD   =1234ABCD   =1234ABCD   =1234ABCD

A signature calculation results in the same value throughout the manufacturing process making it ideal for image tracking and verification

Image signature process

HD-DVD and Blu-ray Process flow