

INTEGRATING FORENSICS TOOLS INTO DIGITAL PRESERVATION WORKFLOWS FOR BORN-DIGITAL MEDIA

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INTRODUCTION

In the Digital Preservation Unit at the University of Michigan Library, we have been researching and testing workflows for processing born digital content on legacy computer media. These actions have been motivated by the acquisition of two significant collections by the UM Library – the Robert Altman and the John Sayles collections which both consist of large volumes of born digital content on old media. Between these two collections, there are many different media varieties of 3.5” and 5.25” floppy disks, 8” floppy disks, Syquest removable hard disks, Kodak Photo CDs and other CD varieties, DVDs, Iomega zip and jaz disks, tape cartridges and external hard drives.

Known risks to born-digital content on legacy media include medium failure or bit rot, obsolescence of media and file formats, and the risk of ‘accidental’, unexpected changes to disk content that may accrue with too much direct physical handling¹. To mitigate these risks in a way that will still render useful and trusted content, the proposed direction for the Robert Altman and John Sayles Digital Media components, as well as for other library special collections that contain born digital media, is to first create bit stream or forensic images of **at-risk** media. The next step would be to work with these bit stream images as surrogates for the original media, by implementing post-imaging workflows that consist of a combination of digital forensics, digital preservation and archival appraisal practices. These proposed interventions align with emerging practices in digital access to and preservation of (almost) obsolete electronic formats, and support an overall objective for persistent access to **at-risk** digital content. Within the OAIS framework, these processes involve the production of archival information packages (AIPs), containing the digital representations, data and metadata that will facilitate long-term preservation and access.

This report looks at a series of fundamental issues that need to be understood and addressed to get such a program underway. It focuses specifically on bit stream imaging as a baseline activity for managing born digital content on legacy computer media. It also looks at some of the media-specific concerns that are pertinent to the Robert Altman and John Sayles collections – at this stage focusing most specifically on 3.5” and 5.25” floppy disks, optical media, and hard drives, and touching on some of the requirements for working with other kinds of legacy media.

There are also higher level policy issues that need to be addressed when considering the handling and use of born-digital media. While this is not a primary focus of this report, some general policy questions would include the choice of preservation strategy/strategies (such as migration or emulation), secure storage, an approach to managing and sustaining access to the content, selection of media and content to prioritize for preservation action, file format support and management, content appraisal, and related issues such as privacy and confidentiality. How these kinds of policy issues are addressed is likely to have both workflow and cost implications. Therefore establishing some policy guidelines through interaction across the relevant library units would be an essential feature of moving this kind of project forward. Additionally, human resource roles and the responsibilities of different library units would need to be clarified.

CONCEPTUAL MODELS AND IMAGING WORKFLOWS

Emory University’s MARBL project was developed along the lines of an overarching content model for processing five computers in the personal archive of writer and literary scholar Salman Rushdie, as illustrated in the content model on page 4.

¹ Digital Forensics for Archivists (June 24 - 25, 2013). Ann Arbor, Michigan: Society of American Archivists. Instructors Cal Lee and Kam Woods

Content Model: processing stages for Rushdie born-digital data before being made available to the public

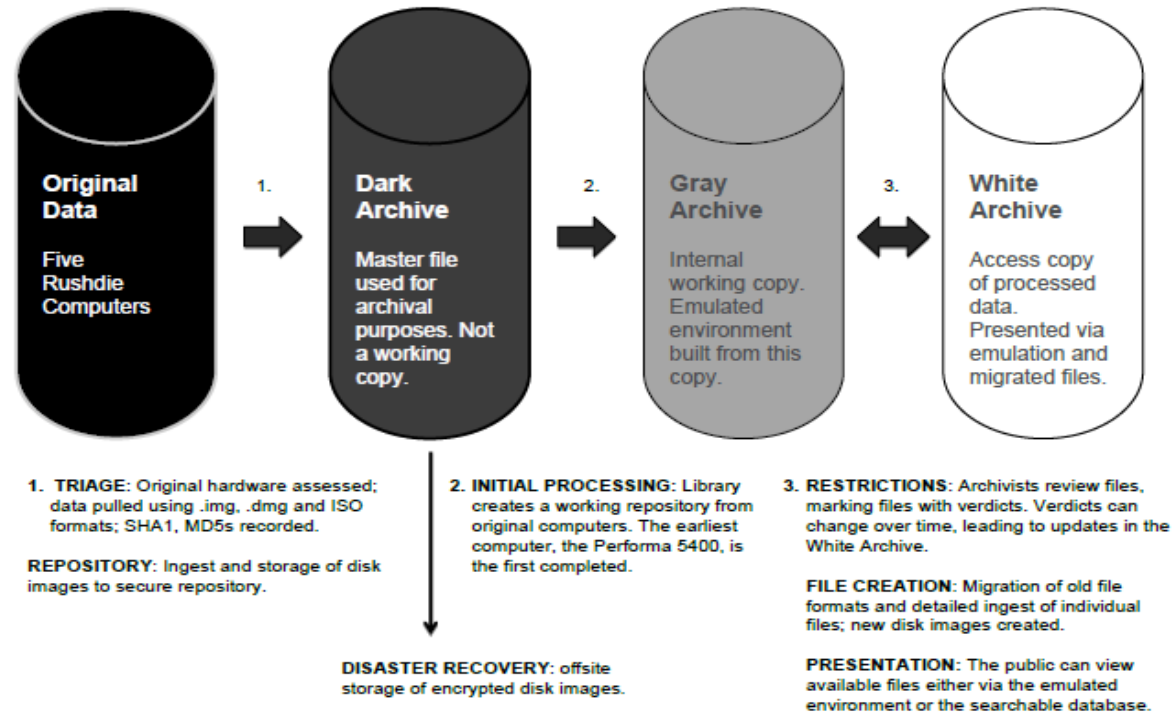


Image source: Caroll, Laura, Erika Farr, Peter Hornsby, and Ben Ranker. 2011. "A Comprehensive Approach to Born Digital Archives." *Archivaria* 72 (Fall): 61–92. journals.sfu.ca/archivar/index.php/archivaria/article/view/13360/14664 (p. 70)

This model translates processing activities into three tangible outputs that emerge from forensic imaging of the computer hard drives in the Rushdie collection: a dark archive as the equivalent of a preservation master collection, a gray archive as a working copy of the collection in which access mechanisms are activated or deactivated, and a final white archive that will be available for researcher access². It deserves serious consideration as it addresses both basic preservation and access.

Another conceptual model is evident in the AIMS project, a collaborative venture of the Universities of Hull in the UK, Stanford University, the University of Virginia and Yale University -- which developed a model for “stewarding” born digital collections with cognizance to its integration with existing archival workflows and standards. Four high level components of born digital collection stewardship were addressed in this project -- collection development, accessioning, arrangement and description, and discovery and access. Like the MARBL initiative, baseline activities of AIMS included the creation of master files through bit stream imaging, followed by metadata capture and processes associated with file level analysis and access. Instead of advocating for a single solution to be adopted by all institutional partners, the needs of different institutional partners were factored into the AIMS model and mapped to specific institutional contexts. As noted in the AIMS final project report, it should be borne in mind that digital preservation was not a priority focus of the AIMS initiative³.

Similarly, but with a more explicit digital preservation agenda, Bitcurator supports archival workflows for born-digital materials by focusing on forensic disk imaging, data triage (analysis of files and file systems), identifying private and sensitive information, and metadata export⁴.

It should be noted that there are more similarities than differences between these models.

In terms of the first step of creating forensic disk images, a typical workflow consists of the following steps, but may need to be tweaked according to the media being imaged, the available technical infrastructure, and what makes the most sense in particular institutional contexts:

- Assign unique ID, label and photograph the disk (if this has not already been done)
- Make sure that disks are write-protected
- Mount disk in appropriate drive
- Create directory and directory folder for saving disk images
- Capture disk image (simultaneously capturing basic administrative and technical metadata, running image validation, and naming files according to standardized file naming convention for digital media)
- Ensure that the disk image and reports generated during the imaging process are stored in the appropriate folder
- Run virus checks
- Transfer to intermediate/secure storage

² Caroll, Laura, Erika Farr, Peter Hornsby, and Ben Ranker. 2011. “A Comprehensive Approach to Born Digital Archives.” *Archivaria* 72 (Fall): 61–92. journals.sfu.ca/archivar/index.php/archivaria/article/view/13360/14664.

³ AIMS Work Group. 2012. “AIMS Born-Digital Collections: An Inter-Institutional Model for Stewardship”. University of Hull, Stanford University, University of Virginia, Yale University. http://www2.lib.virginia.edu/aims/whitepaper/AIMS_final.pdf.

⁴ “BitCurator and Archival Workflows - BitCurator.” 2015. Accessed June 16. http://wiki.bitcurator.net/index.php?title=BitCurator_and_Archival_Workflows.

SETTING UP A FORENSIC IMAGING WORKSTATION

The requirements for setting up one or more imaging workstations depend very much on the extent and complexity of the media to be imaged. Some academic libraries and archives have acquired state-of-the-art forensic technologies to meet the needs of processing born digital media. Initiatives such as Emory University's MARBL project⁵, the Born Digital Forensics Lab at Stanford University Libraries⁶, the digital forensics program at the Johns Hopkins University Archives⁷, and the Digital Preservation Program at the University of Illinois Urbana Champagne⁸ to mention just a few, have set up workstations modelled around the Forensic Recovery of Evidence Device (FRED) which is a robust and reliable but exceedingly expensive platform for imaging and analysis of different kinds of media. An alternative but common approach in the library and archives communities has been to proceed cautiously and to incrementally extend the capacity of in-house developed "rosetta" workstations to meet the needs of growing varieties of born digital media⁹. In both of these cases, a combination of open source and proprietary software options have been considered and applied.

The following components are recommended for setting up an imaging workstation **without** a FRED computer¹⁰¹¹¹²:

- A standard Windows or OS X based PC
- 4-8 GB RAM
- At least 20 GB of storage space for Bitcurator software installation (if using Bitcurator) + storage depending on the size and volume of media that will be imaged
- Memory card reader capable of reading as many different memory cards as possible
- Blue ray player backwards compatible with burned DVDs and CD-ROMs (ideally, the optical media reader should be read-only)
- USB 3.5" floppy disk drive/s that can read both 1.4mb and 800k disks
- External USB 250MB zip drive (backwards compatible with 105MB drive)
- 5.25" floppy disk drive
- Floppy disk controller/s such as the FC5025 controller (for 5.25" floppies), or Kryoflux controller (supporting wider range of magnetic disk formats including 400 and 800k 3.5" floppies)
- Disk drive cleaning kit for 5.25" drives

⁵ Carol, Laura, Erika Farr, Peter Hornsby, and Ben Ranker. 2011. "A Comprehensive Approach to Born Digital Archives." *Archivaria* 72 (Fall): 61–92. journals.sfu.ca/archivar/index.php/archivaria/article/view/13360/14664.

⁶ "Born-Digital / Forensics Lab | Stanford University Libraries." 2015. Accessed May 18.

<http://library.stanford.edu/research/digitization-services/labs/born-digital-forensics-lab>.

⁷ "Digital Forensics in the Archives | The Sheridan Libraries Blog." 2015. Accessed May 18.

<http://blogs.library.jhu.edu/wordpress/2013/11/digital-forensics-in-the-archives/>.

⁸ "Born Digital Content Preservation." 2015. Accessed May 18. http://www.library.illinois.edu/prescons/services/born_digital/.

⁹ Knight, Gareth. 2012. Forensic Investigation of Digital Objects Final Project Report. London: Kings

College. https://fido.cerch.kcl.ac.uk/wp-content/uploads/2012/12/FIDO-Final-Report_v12.pdf.

See also the workstation setup at the Bentley Historical Library

¹⁰ "Building a Digital Curation Workstation with BitCurator (update) | BitCurator." 2015. Accessed May 12.

<http://www.bitcurator.net/building-a-digital-curation-workstation-with-bitcurator-update/>.

¹¹ Knight, Gareth. 2012. Forensic Investigation of Digital Objects Final Project Report. London: Kings

College. https://fido.cerch.kcl.ac.uk/wp-content/uploads/2012/12/FIDO-Final-Report_v12.pdf.

¹² Meister, Sam. 2013. "Getting Bits off Disks: Using Open Source Tools to Stabilize and Prepare Born-Digital Materials for Long-Term Preservation". Slide presentation presented at the Best Practices Exchange, University of Montana, November 13.

<http://www.slideshare.net/samalanmeister/getting-bits-off-disks-using-open-source-tools-to-stabilize-and-prepare-borndigital-materials-for-longterm-preservation>.

- Forensic hardware write blocker/s as per media requirements (Tableau or Wiebetech are the two most widely referenced brands)
- Hard drive enclosure

In addition to these workstation basics, specific requirements of the Altman and Sayles digital media components include a need to make provision for media such as 8” floppy disks, Iomega jaz disks, 2 Syquest removable hard disks, 4 x 8mm AIT cartridges, and 1 DDS-2 cartridge. This would expand the basic workstation requirements to include the following:

- 8-inch (200mm) disk drive¹³ (this would have to be used in combination with the Kryoflux floppy controller – see list above, as well as appendices)
- Iomega portable SCSI 2GB Jaz drive
- SQ3105 drive/SQ310 (105 MB), or the SQ3270/SQ327 (270 MB). The latter is backwards compatible.
- Sony AIT1 external tape drive
- HP DDS-2 tape drive. Could include one of the following: HP Surestore/Storage Works DAT8 (write/read); HP Surestore/Storage Works DAT 24/24x6 (write/read); HP Storage Works DAT40 Hotplug (write/read); HP Surestore/Storage Works DAT40/40x6 (write/read); HP Storage Works DAT24 USB (write/read); HP Storage Works DAT40 USB (write/read)¹⁴

If the library were to pursue the option of **setting up a FRED-enabled workstation**, it would be acquiring a stable and advanced preconfigured platform for media imaging and analysis, but would still need to adapt the system for specific media needs. It would therefore still be necessary to acquire legacy media peripherals such as the following:

- USB 3.5” floppy disk drive/s that can read both 1.4mb and 800k disks
- External USB 250MB Iomega zip drive
- Iomega jaz drive
- 5.25” floppy disk drive/s
- Floppy disk controller such as the FC5025 controller, Catweasel or Kryoflux controller
- Disk drive cleaning kit for 5.25” drives
- 8-inch (200mm) disk drive (to be used in combination with Kryoflux controller)
- Iomega portable SCSI 2GB Jaz drive
- SQ3105 drive/SQ310 (105 MB), or the SQ3270/SQ327 (270 MB)
- Sony AIT1 external tape drive
- HP DDS-2 tape drive
- Additional write blockers if required

Bearing the latter in mind, setting up a fully equipped forensics workstation **with a FRED computer** would include the following baseline components, and the legacy media listed above would need to be added:

¹³ “Floppy Disk - Wikipedia, the Free Encyclopedia.” 2015. Accessed June 24. https://en.wikipedia.org/wiki/Floppy_disk.

¹⁴ “HP StorageWorks DDS/DAT Media - DDS/DAT Media Compatibility Matrix.” 2015. Accessed June 16. http://h20564.www2.hp.com/hpsc/doc/public/display?docId=emr_na-lpg50457.

Baseline FRED components¹⁵

Specifications	<ul style="list-style-type: none"> • 23 3/4" High, 8 3/8" Wide, 25 1/4" Deep - 80 lbs • Intel Core i7-5820K CPU (Hex Core Processor), 3.3 GHz, 10MB Intel Smart Cache, 5 GT/s DMI • 32 GB (4x8GB)PC3-17000 DDR4 2133 MHz Memory • 1 x 256 GB Solid State SATA III Drive - OS Drive • 1 x 128 GB Solid State SATA III Drive - Temp/Cache/DB Drive • 1 x 2.0 TB 7200 RPM SATA III Hard Drive - Data Drive installed in HotSwap Bay1 • Nvidia GTX 750Ti 2GB 128 bit DDR5 PCI-Express Video Card with 1 VGA (D-Dub), 1 HDMI, and 2 DVI ports - supports up 4 displays • 22" WideScreen LCD Monitor with Built-in Speakers
Hardware write blocking	<p>Digital Intelligence UltraBay 3d Hardware Write-Blocker with touch screen display:</p> <ul style="list-style-type: none"> • Integrated IDE Drive Write Blocker • Integrated SATA Drive Write Blocker • Integrated SAS Drive Write Blocker • Integrated USB 3.0/2.0 Write Blocker • Integrated FireWire IEEE 1394b Write Blocker <p>Digital Intelligence Integrated Forensic Media Card Reader - Read-Only and Read/Write switchable</p>
Software	<ul style="list-style-type: none"> • Windows 8.1 Professional (64 bit) • Also includes: DOS (Win98 Standalone), SUSE Professional Linux (64 bit)
Detailed specifications	<ul style="list-style-type: none"> • ATX Tower Case 12 x 5 1/4" Bays • 1100 Watt Modular power supply • i7 Motherboard with Intel X99 Chipset • 7 PCI-Express 3.0(x16) Slots • 8 ports Intel 6 Gb/s SATA Controller • 1 port Intel SATA Express Controller (or 2 x SATA 6 Gb/s ports) • 1 port ASMedia SATA Express Controller (or 2 x SATA 6 Gb/s ports) • 8 Channel High Definition Audio CODEC featuring Crystal Sound 2 • 2 RJ45 LAN ports (Intel I210-AT, 1 x Gigabit LAN Intel I218LM, 1 x Gigabit LAN Controllers) • 2 eSATA 6 Gb/s ports - ASMedia controller • 16 USB 3.0/2.0 ports - 13 Back Mounted, 3 Front Mounted • 1 Write Blocked USB 3.0/2.0 port - Front Mounted • 2 FireWire IEEE 1394b (800 MB/s) ports - 1 Back Mounted, 1 Front Mounted(Write Blocked) • 2 x Shock Mounted SATA Removable Hard Drive Bays (IDE Capable) • 4 x HotSwap Shock Mounted Universal (IDE/SATA compatible) Removable Hard Drive Bays • BD-R/BD-RE/DVD±RW/CD±RW Blu-ray Burner Dual-Layer Combo Drive • Extendable/Retractable Imaging Workshelf with integrated ventilation • 103 key Keyboard and Mouse Combo – Wireless • Toolbox containing: Adapters, Cables, Digital Camera, Security Screwdriver Set and OEM Documents • Other Software included: Symantec Ghost, CD Authoring Software, DRIVESPY, IMAGE, PDWIPE, PART, and PDBLOCK • Warranty 1 year parts and labor
Tape option at an additional cost	<ul style="list-style-type: none"> • LTO Ultrium 5 Internal Tape Drive (1.5TB Native / 3.0TB Compressed) (Adding this option eliminates one HotSwap bay)
Toolbox	<ul style="list-style-type: none"> • CD Case: Containing systems restore media • System Keys: For removeable hard drive bays and front case bezel • Adapters and Cables: Cables and adapters to image and process internal/external drives including SAS, SATA, IDE, microSATA, SATA LIF, MacBook Air Blade Type SSDs, mini/micro SSD cards, 1.8 inch IDE (iPod) and 2.5 inch IDE (laptop) • Digital Camera • Security Screwdriver Set: A varied assortment of popular security bits for opening computer enclosures that may have been locked down in a corporate environment.

¹⁵ "FRED." 2015. Accessed May 20. <https://www.digitalintelligence.com/products/fred/>.

USING WRITE BLOCKERS

Write blocking is an essential feature of the bit stream imaging process as it reduces the likelihood of overwriting data on the source drive during imaging. Choosing an appropriate write blocker depends entirely on the media that is being imaged. The table below shows some of the standard write-blocking options for various media.

MEDIA	OPTIONS
3.5" floppy disks	Write protect 3.5" disks by moving the tab / slider in the top left corner of the disk to "open"
5.25" disks	Write protect 5.25" disks by covering the notch on the upper right side of the disk with a non-transparent tape (such as masking tape)
Syquest drives	Write protect Syquest drives by turning the write protect cylinder on the bottom left side of the case clockwise, until the red write protect display is visible
Jaz disks	Iomega software write protection
Zip disks	Iomega software write protection
USB drives	Connect to appropriate forensic write blocker
Memory cards	Connect card reader to appropriate forensic write blocker
Hard drives	Connect hard drive to appropriate forensic write blocker

Some additional notes on write protection:

- Bitcurator includes software-based write protection.
- The Kryoflux floppy controller includes built-in write protection.
- The MARBL project at Emory University reported that the use of hardware write blockers for 3.5" disks added another layer of complication, and that the use of too many hardware intermediaries may have had something to do with high rates of imaging errors in the early stages of the MARBL project¹⁶.

FORMATS FOR SAVING DISK IMAGES

There are a number of examples of disk image formats on the market. Within the preservation community, those most commonly referenced for library and archival purposes are EnCase image files (E01), Advanced Forensics Format (AFF), Raw (DD), ISO for CD-ROM and IMG files for magnetic or optical disks¹⁷. ISO and IMG files are variants of raw images, typically used as extensions for saving image files of CDs in the case of ISO¹⁸, and floppy disks in the case of IMG files¹⁹. Deciding which file format/s are most appropriate is an important issue that has direct bearing on future workflow processes, and on the extent to which content will be accessible and sustainable in the future.

¹⁶ Waugh, Dorothy. n.d. "A Dogged Pursuit: Capturing Forensic Images of 3.5" Floppy Disks." *Practical Technology for Archives*. http://practicaltechnologyforarchives.org/issue2_waugh/.

¹⁷ Digital Forensics for Archivists (June 24 - 25, 2013). Ann Arbor, Michigan: Society of American Archivists. Instructors Cal Lee and Kam Woods (p.198)

¹⁸ "What's an ISO? A CIF? BIN and CUE? .DAT?" 2015. Accessed March 24. <http://www.magiciso.com/tutorials/miso-whatiso.htm>.

¹⁹ "IMG (File Format)." *Wikipedia*. http://en.wikipedia.org/wiki/IMG_%28file_format%29.

EnCase files are for the most part “program-specific”²⁰. They are widely used within the forensics community, and regarded “[as] the *de facto* standard for forensic analysis in law enforcement”²¹. While this format is supported by the robust EnCase platform, its dependence on proprietary software has been an issue of concern. This concern has been partly addressed by an option to open Encase files in open source tools, an option which recently became available in the LibEWF library²². EWF files in excess of 2GB is split into a series of files within the same directory, and labelled with the extensions .E01, E02, .E03, etc²³.

RAW (DD) and AFF image files are “independent” from any specific forensic packages²⁴. While RAW image files are widely used and highly compatible with most forensic tools, the major drawbacks of using the RAW image format is its lack of compression resulting in large and sometimes difficult to maintain files, and its lack of support for embedding important technical metadata. Both of these features, in addition to other strong features, are supported within the EnCase and AFF formats.

AFF in particular was created in response to some of these drawbacks of RAW and EWF formats, importantly also as an open source format supporting forward and backward compatibility²⁵. There are three variants of AFF files – AFF, which is a single image file consisting of embedded metadata; AFD, which splits an AFF file into multiple files according to user specifications, and is stored in a single directory; and AFM, which consists of DD disk images coupled with a separate file of AFF data²⁶. It has also been noted that AFF files in excess of 4GB may be difficult to store in some file systems, and that uncompressed files are a bit larger than the disks that have been imaged²⁷. AFF is however no longer being developed²⁸, and its strongest features have been included in a new AFF4 specification²⁹. At this stage it appears that there has been little uptake of AFF4 into forensic imaging tools such as FTK Imager and Bitcurator, though there is some speculation that its use is likely to increase in the future³⁰.

In reference to the three widely referenced formats of E01, AFF and RAW image files the discussion above narrows the options to E01, AFF and AFF4 formats. It is worthwhile noting then that file format selections that support digital preservation have generally been guided by five main criteria - adoption (how widely used), technological dependencies (dependence on other technologies), disclosure (availability in the public domain), transparency (how readily can it be identified and accessed), and metadata support (is metadata provided within the format)³¹. Other assessment criteria that might help to particularize the results to specific institutional contexts include reusability, robustness, stability, and intellectual property³². The table on page 12 is an evaluation of formats according to some of these

²⁰ “Forensics File Formats.” *Forensics Wiki*. http://www.forensicswiki.org/wiki/Category:Forensics_File_Formats.

²¹ Garfinkel, Simson, David Malan, Karl-Alexander Dubec, Christopher Stephen, and Cecile Pham. 2006. “Advanced Forensic Format: An Open Extensible Format for Disk Imaging.” In *Advances in Digital Forensics II*. Vol. 222. Springer.

²² Ibid.

²³ Knight, Gareth. 2011. *Forensic Disk Imaging Report*. Version 1.0. Forensic Investigation of Digital Objects (FIDO). London: Kings College. <https://fido.cerch.kcl.ac.uk/wp-content/uploads/2012/11/FIDO-Forensic-Disk-Imaging-Report-v1.pdf>

²⁴ Ibid

²⁵ Garfinkel, Simson, David Malan, Karl-Alexander Dubec, Christopher Stephen, and Cecile Pham. 2006. “Advanced Forensic Format: An Open Extensible Format for Disk Imaging.” In *Advances in Digital Forensics II*. Vol. 222. Springer.

²⁶ Knight, Gareth. 2011. “Forensic Disk Imaging Report”. Version 1.0. Forensic Investigation of Digital Objects (FIDO). London: Kings College. <https://fido.cerch.kcl.ac.uk/wp-content/uploads/2012/11/FIDO-Forensic-Disk-Imaging-Report-v1.pdf>.

²⁷ Knight, Gareth. 2011. *Forensic Disk Imaging Report*. Version 1.0. Forensic Investigation of Digital Objects (FIDO). London: Kings College. <https://fido.cerch.kcl.ac.uk/wp-content/uploads/2012/11/FIDO-Forensic-Disk-Imaging-Report-v1.pdf>

²⁸ “AFF.” *Forensics Wiki*. <http://www.forensicswiki.org/wiki/AFF>.

²⁹ “AFF4.” *Forensics Wiki*. <http://www.forensicswiki.org/wiki/AFF4>.

³⁰ Knight, Gareth. 2011. *Forensic Disk Imaging Report*. Version 1.0. Forensic Investigation of Digital Objects (FIDO). London: Kings College. <https://fido.cerch.kcl.ac.uk/wp-content/uploads/2012/11/FIDO-Forensic-Disk-Imaging-Report-v1.pdf> (p.6)

³¹ Todd, Malcolm. 2009. *File Formats for Preservation*. Report 09-02. DPC Technology Watch Series. Digital Preservation Coalition.

³² Ibid.

criteria, and is an adaption of, and slight modification to that presented by the Kings College-based *Forensic Investigation of Digital Objects* project³³.

For particular media types, the following options are recommended for consideration:

- Floppy Disks and Zip disks: -- save as AFF, E01, DD, or IMG files
- CDs: -- save CDs as ISO (image file), or simply extract contents as per folder structure
- Hard drives: -- save as AFF or E01 files

³³ Ibid, p.9

Evaluation of formats:

	Adoption	Technological Dependencies	Disclosure	Transparency	Metadata Support	Robustness	Reusability	Stability	Intellectual property	Additional notes
RAW / DD	Widespread.	Major weakness is the reliance on 3rd parties for metadata support, disk spanning and compression.	Yes	Independent file format that can be opened with most forensic tools.	No embedded metadata support. Administrative and technical metadata on the image capture process needs to be stored in separate files. Extension tools such as dcfldd and dccidd can be used to create hash values, and store them separately from the image. Storing technical and administrative metadata in separate files increases the likelihood of losing the metadata associated with an image, over time.	?	Can be mounted on virtually any platform.	Widespread development support.	?	Cannot be compressed, even if drive contains very little data ³⁴ .
AFF	Less use than RAW or EnCase formats.	Open source format that supports forward and backward.	Yes	Independent file format that can be opened with most forensic tools.	Fixity and metadata support. Choice of storing metadata inside image file, or as separate file ³⁵ . Metadata can be parsed, mapped or appended to existing preservation metadata schemas ³⁶ . Can store any kind of	?	Extensible format.	This is still in question given that AFF is no longer being developed. Its incorporation into AFF4 might increase its stability.	Code can be freely used in open source or proprietary applications ³⁷ .	Large files, which can be compressed.

³⁴ Garfinkel, Simson. 2006. "AFF: A New Format for Storing Hard Drive Images." *Communications of the ACM* 49 (2): 85–87. <http://simson.net/clips/academic/2006.CACM.AFF.pdf>.

³⁵ Garfinkel, Simson. 2006. "AFF: A New Format for Storing Hard Drive Images." *Communications of the ACM* 49 (2): 85–87. <http://simson.net/clips/academic/2006.CACM.AFF.pdf>.

³⁶ Woods, Kam, Christopher A. Lee, and Simson Garfinkel. n.d. "Extending Digital Repository Architectures to Support Disk Image Preservation and Access." <http://www.ils.unc.edu/callee/p57-woods.pdf>.

³⁷ Garfinkel, Simson. 2006. "AFF: A New Format for Storing Hard Drive Images." *Communications of the ACM* 49 (2): 85–87. <http://simson.net/clips/academic/2006.CACM.AFF.pdf>.

	Adoption	Technological Dependencies	Disclosure	Transparency	Metadata Support	Robustness	Reusability	Stability	Intellectual property	Additional notes
					forensic metadata that is required.					
EWF	Widespread. Default standard within the digital forensics community.		?	Program specific file format, with adaptations for access using open source tools such as LibEWF	Fixity and metadata support, meaning that metadata is always bundled with the image file. Restrictions on type and quantity of metadata that can be associated with image, but this may be accomplished with external tools.	Supports block by block checksums meaning that specific sectors that are corrupted can be pointed out.		Widespread development support.	?	Large files, which can be compressed.

IMAGING SOFTWARE

There are many software tools that support disk imaging³⁸. However, not all of these generate stable or forensic images, and sometimes there is little apparent information on their integration into digital preservation workflows. FTK Imager and the Bitcurator imaging tool, Guymager, are two options that have been tested and applied in libraries and archives over at least the last 7 years. Both have also undergone modifications over this period. Disk Image software is also prepackaged with Device Side Data's FC5025 floppy controller (for 5.25" disks), and a more costly software option is available with the Kryoflux floppy disk controller (for 3.5", 5.25", 3", and other floppy disk variants). There are also software options such as MagicISO, CDRDAO and others for extracting or imaging the contents of CDs. More details on specific software options are available in the sections looking at specific media formats.

FTK Imager

FTK Imager is a forensics imaging and data preview tool developed by AccessData³⁹. It is free but proprietary. The software can be used for creating disk images, for viewing the technical and administrative metadata associated with a disk image, for viewing file attributes, for identifying and flagging sensitive data, for file naming and labeling, and for viewing files. FTK Imager featured centrally in the workflow processes of the AIMS partnership between the University of Hull in the UK, Stanford University, the University of Virginia and Yale University⁴⁰. It is also the standard imaging tool used by the Bentley Historical Library.

In addition to being able to create forensic images, FTK Imager also allows for the creation of logical images in which only the logical contents of a disk would be captured. This means that deleted files will not be captured.

FTK Imager 3.2.0.0 provides options for capturing images in RAW (dd), EWF (e01), AFF and SMART formats. Irrespective of the chosen file format, three files are generated during the imaging process – the image file (.dd, OR .e01, OR .aff), a text file (.txt), and an excel spreadsheet (.csv). The text files contain metadata on the imaging process such as the “case information” inputted by the user/imager during the imaging process, technical information on the image source, and image verifications. The .csv file provides a more detailed tabulated report which includes a directory of disk contents/ file names, full paths for each file, file sizes, when files were created, when files were modified, when files were accessed, and if the disk contains deleted files.

FTK Imager also provides visible options for saving only the logical contents of a disk. Logical files are saved with a .AD1 extension.

Using a write blocker, FTK Imager can also be used to preview the contents of old media⁴¹.

³⁸ See: Comparison of disk image software, http://en.wikipedia.org/wiki/Comparison_of_disc_image_software

³⁹ *FTK Imager User Guide*. 2012. Utah: AccessData. https://ad-pdf.s3.amazonaws.com/Imager%203_1_4_UG.pdf

⁴⁰ AIMS Work Group. 2012. “AIMS Born-Digital Collections: An Inter-Institutional Model for Stewardship”. University of Hull, Stanford University, University of Virginia, Yale University. http://www2.lib.virginia.edu/aims/whitepaper/AIMS_final.pdf.

⁴¹ Hull History Centre. n.d. “Idiot Guide No. 3: FTK Imager.”

<http://www.hullhistorycentre.org.uk/discover/pdf/Idiot's%20Guide%20-%20FTK%20Imager.pdf>.

Guymager

Guymager is an open source forensic imaging application and is included in the Bitcurator suite of tools. It is used widely by the growing library and archives community of Bitcurator users. Guymager, as available in Bitcurator 1.2.1 provides options for saving file images in RAW (.dd), EWF (.e01) and AFF formats.

Guymager generates two files for each image process, irrespective of whether images are saved as .dd, .e01, or .aff files – the image file, as well as an informational file saved with a .info extension. This informational file is a Guymager generated text file containing metadata on the image acquisition process.

FC5025 Disk imager software

The software that accompanies the FC5025 floppy controller is compatible only with Windows 32-bit installations⁴². Since the FC5025 controller supports only the imaging of 5.25” disks, the use of the accompanying software is limited to this format. Its use is also dependent on prior and specific knowledge of disk types and file systems. If these are not set correctly before attempting to capture an image, the disk will most likely not be read or not read accurately⁴³. The software only supports IMG output types.

Kryoflux DiskTool Console (DTC)

The Kryoflux DiskTool Console (DTC) is downloadable from the Kryoflux website at no cost for non-commercial use, but with considerable costs for commercial including university-based use. It can be used on Windows, Mac OSX, Linux and Amiga OS4⁴⁴. The Kryoflux was developed primarily for high density 3.5” (1.44mb), and 5.25” (1.2mb) drives, but reportedly also works with selected 3” and 8” drives, and some 3.5” and 5.25” variants⁴⁵. As with the FC5025, imaging works best when the proper disk types and file systems are specified before imaging. The Kryoflux is known to have a much greater success rate than other floppy controllers, and is also known for supporting a much wider variety of legacy disk formats.

MEDIA CHARACTERISTICS AND IMAGING

Floppy Disks

The lifespan of floppy disks are thought to be under 10 years⁴⁶. There are several influencing factors, which include the extent of physical handling, moisture, exposure to magnetic interference, dust, dirt and physical storage conditions⁴⁷. Like other magnetic media, floppy disks also have their own “inherent vice” and degrade naturally over time because of their physical composition. A typical example is that

⁴² Maryland Institute for Technology in the Humanities. “Use Guide for the FC5025 Floppy Controller: FC5025 Software Instructions”. Maryland Institute for Technology in the Humanities (MITH). <http://mith.umd.edu/vintage-computers/fc5025-operation-instructions>.

⁴³ Ibid.

⁴⁴ “Kryoflux Quickstart Manual.” <http://www.kryoflux.com/?page=download#docs>.

⁴⁵ “Kryoflux: High Definition Flux Sampler for USB (Manual Revision 1.11).” 2014. István Fábíán and KryoFlux Products & Services Limited. <http://www.kryoflux.com/?page=download#docs>.

⁴⁶ Preservation 101. Deterioration of Film and Electronic Media. http://unfacilitated.preservation101.org/session3/expl_iv_mm-disks.asp

⁴⁷ Floppy Disks. <http://www.pcguides.com/care/care/mediaFloppies-c.html>

data is stored as tiny magnetic fields that eventually fade or can be corrupted because of close proximity to other data fields⁴⁸. Other common floppy disk problems also include head misalignment and already existing copy protection settings⁴⁹ that limit access to the data on the disk.

Media compatibility issues also affect how floppy disks can be read and accessed. Across the floppy disk spectrum there are differences in size, disk storage capacity, density rates, and single vs. double-sided disks⁵⁰. Not all of these disks are readable in the same drives and computer systems⁵¹. Moreover, access to these disks more than 20 years later is dependent on media that, for the most part, are already obsolete, or media that are difficult to locate and make work.

Physical description of floppy disks in the Robert Altman and John Sayles collections:

The floppy disks in the Robert Altman collection represent an array of 360 kb, 1.2mb, 400k, 800k, 720k, 1.4mb and 2mb disks. As per the inventory of digital media in the Robert Altman collection, there are 29 8” floppy disks, 39 5.25” disks, and 473 3.5” disks⁵². These translate to roughly 712mb. Included here, are at least 20 “flippy” or double-sided 5.25” disks, which are reportedly the oldest kinds of floppy disks that were used in the first IBM PCs⁵³.

It is apparent from the inventory that the 8” disks were in use from 1980 – 1984, the 5.25” disks were used from the mid-1980s to 1997, and the 3.5” disks were in use between the mid-1980s and 2003. The oldest floppy disks in the Altman collection are therefore around 30 years old, and the most recent are around 12 years old. The life expectancy of magnetic media has been exceeded at both ends of this spectrum, implying that a serious intervention is necessary if the media contains content that will benefit scholarship over the long term.

In the John Sayles collection, there are about 220 5.25” and about 163 3.5” floppy disks⁵⁴, translating to around 494 mb. It is anticipated that except for the 8” disks, the physical characteristics of these media are highly similar to the Robert Altman digital media. While many of the disks that are listed in the John Sayles Collection finding aid are undated, the earliest recorded date is 1986 and the most recent is 1998. As in the case of the Robert Altman collection, the life expectancy for these disks has already been dramatically exceeded.

Floppy disk imaging

The forensic imaging workstation at the Library’s Buhr facility is currently configured to process an estimated 580 3.5” disks (1.4mb and 720k) in the Robert Altman and John Sayles collections. At this stage, the workstation is not fitted with the capacity to process 8” floppy disks, or to image 400k and 800k 3.5” disks, or to image different varieties of 5.25” disks. Additional equipment would be required to fulfil these tasks. Access to the 8” disks will require an 8” drive and a floppy disk controller capable of supporting access to 8” disks. The necessary prerequisites for accessing the 5.25” disks include the availability of 5.25” drives capable of reading single and double-sided double density and high density

⁴⁸ Media Use and Storage Life. <http://www.pcguides.com/care/care/media.htm>

⁴⁹ Guerrero, Miriely. Removable Media and the Use of Digital Forensics, <http://bentley.umich.edu/dchome/resources/RemovableMediaReport.pdf>

⁵⁰ Floppy Disk. http://en.wikipedia.org/wiki/Floppy_disk

⁵¹ UM Computing News, volume 5 1990, p.17-19

⁵² Kremyar, Jenny. The Robert Altman Archive Digital Physical Media Collection

⁵³ “Floppy Disk - Wikipedia, the Free Encyclopedia.” 2015. Accessed March 24. http://en.wikipedia.org/wiki/Floppy_disk#5.25-inch_floppy_disk.

⁵⁴ Finding Aid for the John Sayles Archive

disks, as well as a floppy drive controller. Access to the 400k and 800k 3.5” disks will depend on the availability of an 800 k drive and floppy controller hardware to read 400k and 800k disks. It should however be noted that access to 8” disks present a special challenge. Media support for accessing these disks are becoming increasingly difficult to locate, and there are a limited number of vendors country-wide who offer this service.

While determinations on how to proceed will be informed by broader policy questions on the levels and extent of support that the library is willing to develop in-house for preservation and access to content on legacy media, the table below provides some equipment options for reading and imaging 400 and 800k 3.5” disks, and 1.2mb and 360k 5.25” disks. (It does not include specifications for 8” disks)

DISK TYPE	LEGACY EQUIPMENT AND/OR EXTERNAL DRIVE	FLOPPY DRIVE CONTROLLER	NOTES
3.5” 400k and 800k disks	<i>Option 1:</i> Macintosh 800k drive (M0131), noted as working with third party disk controllers, but incompatible with Apple II.	Kryoflux or Catweasel controller	<ul style="list-style-type: none"> The latest version of the Catweasel controller is noted as being sold out and discontinued⁵⁵.
	<i>Option 2:</i> Apple 3.5” drive (A9M0106), in combination with, the Apple IIgs which has a built-in 800k disk controller; OR the Apple IIe, which has a SuperDrive controller	N/A	
	<i>Option 3:</i> Apple 3.5” drive (A9M0106)	Kryoflux or Catweasel controller	<ul style="list-style-type: none"> The latest version of the Catweasel controller is noted as being sold out and discontinued⁵⁶.
	<i>Option 4:</i> Apple FDHD External (G7287), in combination with the Apple IIgs, OR the Apple IIe, which has a SuperDrive controller	N/A	

⁵⁵ “Versalia Online - Catweasel MK4plus PCI.” 2015. Accessed March 24. http://www.vesalia.de/e_catweaselmk4plus.htm.

⁵⁶ “Versalia Online - Catweasel MK4plus PCI.” 2015. Accessed March 24. http://www.vesalia.de/e_catweaselmk4plus.htm.

DISK TYPE	LEGACY EQUIPMENT AND/OR EXTERNAL DRIVE	FLOPPY DRIVE CONTROLLER	NOTES
	<i>Option 5:</i> Apple FDHD External (G7287)	Kryoflux or Catweasel controller	<ul style="list-style-type: none"> The latest version of the Catweasel controller is noted as being sold out and discontinued⁵⁷.
3.5" disks (1.4mb)	3.5" drive with built in write blocker (Digital Intelligence)		<ul style="list-style-type: none"> Drives with built-in write blockers are hard to find, but provides an additional layer of stability to the imaging process
5.25" 1.2mb and 360k disks	5.25" floppy drive	FC5025, Kryoflux or Catweasel controller	<ul style="list-style-type: none"> The FC5025 does not support 'flippy' disks Softpres provides a 3-part video tutorial for using a Kryoflux to access flippy disks by modifying the disk drive
8" disks	8" readers, specifications still to be determined OR outsource as necessary	Kryoflux controller	
Other:			
Molex connector, needed for powering internal drives			

Software tools

Some software options for floppy disk imaging are as follows:

- Guymager (Bitcurator)
- FTK Imager
- FC5025 Disk imager software
- Kryoflux DiskTool Console

⁵⁷ "Versalia Online - Catweasel MK4plus PCI." 2015. Accessed March 24. http://www.vesalia.de/e_catweaselmk4plus.htm.

Optical Media

While optical media have generally been regarded as much more of a stable medium than floppy disks, they are also susceptible to physical degradation over time. Also, hardware obsolescence is expected⁵⁸, and in some cases has already been demonstrated with examples such as the discontinuation of support for reading Kodak Photo CDs. The longevity of the optical disks themselves are however influenced by several factors that include user-controlled issues such as physical handling and environmental conditions, and other inherent issues such as the type, manufacturing quality, condition of the disk prior to recording, and the quality of the recording⁵⁹.

ISO9660, also known as Compact Disk File System (CDFS), is the standard file system for optical discs. Other CD file systems include Joliet, UDF, HSG, HFS and HFS+. An optical disc may also contain multiple file systems⁶⁰.

CDs typically store 700MB of data. However, some CD varieties such as CD-RW store 570MB. DVDs typically store 4.7GB on a single side, but some DVDs can store up to 17GB.

Unlike CD-ROM and CD-R, CD-RW can have data written to it many times⁶¹, and it is these kinds of seemingly trivial features that need to be borne in mind when designing digital preservation workflows. A similar situation applies for DVDs.

Optical media imaging

Optical media imaging can be straightforward, or quite complicated depending on what is being imaged. CDs and DVDs are typically imaged to create ISO files that “contain the data contents of every written sector of an optical disc, including the optical disc file system if one is present”⁶². While ISO is a “media-independent” format, the source disk and hence the derived image may contain files and features that are dependent on file systems other than the standard ISO9660 in the case of CDs, or files that are media or program-specific^{63,64}. Simply put, in the case of CDs, an ISO file may not contain ISO9660 filesystem data, or some of the data in the file may have other dependencies⁶⁵. Because of this it may not be the best solution to image *all* optical media varieties, and consideration would need to be given to circumstances in which it might be most appropriate to simply extract the content. In fact, it is known that ISO image files do not offer any straightforward solutions for, and may not be appropriate for access to the content of

⁵⁸ “Exploring Inherent Vice: Optical Media.” n.d. *Preservation 101: Deterioration of Film and Electronic Media*. http://unfacilitated.preservation101.org/session3/expl_iv_op.asp.

⁵⁹ Byers, Fred. 2003. *Care and Handling of CDs and DVDs: A Guide for Librarians and Archivists*. Washington, D.C.; Gaithersburg, MD: Council on Library and Information Resources; National Institute of Standards and Technology Administration. <http://www.clir.org/pubs/reports/pub121/pub121.pdf>.

⁶⁰ Hayes, Darren R. 2015. “Removable Memory | Handling Computer Hardware in a Computer Forensics Investigation | Pearson IT Certification.” Accessed April 8. <http://www.pearsonitcertification.com/articles/article.aspx?p=2271195&seqNum=4>.

⁶¹ Hayes, Darren R. 2015. “Removable Memory | Handling Computer Hardware in a Computer Forensics Investigation | Pearson IT Certification.” Accessed April 8. <http://www.pearsonitcertification.com/articles/article.aspx?p=2271195&seqNum=4>.

⁶² Library of Congress, National Digital Information Infrastructure and Preservation Program (NDIIP). 2015. “ISO Disk Image File Format.” *Sustainability of Digital Formats: Planning for Library of Congress Collections*. Accessed April 8. <http://www.digitalpreservation.gov/formats/fdd/fdd000348.shtml>.

⁶³ Ibid

⁶⁴ Hayes, Darren R. 2015. “Removable Memory | Handling Computer Hardware in a Computer Forensics Investigation | Pearson IT Certification.” Accessed April 8. <http://www.pearsonitcertification.com/articles/article.aspx?p=2271195&seqNum=4>.

⁶⁵ “What’s an ISO? A CIF? BIN and CUE? .DAT?” 2015. *Magic ISO Maker*. Accessed April 8. <http://www.magiciso.com/tutorials/miso-whatiso.htm>.

tracked audio CDs, interactive CDs and multisession disks⁶⁶. Therefore, while ISO disk images meet the needs of bitstream preservation, there is more that needs to be figured out regarding long-term access to the content⁶⁷.

The forensic imaging workstation at Buhr is currently fitted with a standard CD-RW and DVD-RW Ultra Speed drive. It should be noted that this drive is not appropriate for reading or imaging some kinds of optical media such as CD-RW and DVD-RW disks which should only be read in read-only drives to prevent unintended changes to the source content⁶⁸.

Imaging optical media with Bitcurator

Bitcurator provides tools for imaging or copying optical media through its available command line tools, since its standard imaging tool, Guymager, is not equipped to do this⁶⁹. These command line options are cdrdao, dd, dcfldd, and ddrescue.

Bitcurator command line options for optical media:

CDRDAO (Disk-at-once recording)	Used for recording audio or data CD-Rs, CD-RW, or mixed mode disks ⁷⁰ . This process generates files with a .dao file extension
DD	An imaging tool that enables copying of all the raw data on an optical disk, resulting in an ISO image file ^{71,72} .
DCFLDD	Provides an extension to dd through support for error checking, output management, and basic metadata support. It therefore provides a forensic imaging option to the DD format ⁷³ .
DDRESCUE	A data recovery tool that extracts the good data when there are disk errors (used for both optical disks and hard drives) ⁷⁴ .

Imaging optical media with FTK Imager

FTK Imager also provides some options for imaging CDs. There are options for saving disk image files in ISO format, as well as saving the logical contents of a disk only. The bitstream imaging process in FTK Imager generates three files – an ISO image file, a CUE file that documents how data or tracks are laid out on a CD or DVD⁷⁵, and a text file containing basic administrative and technical metadata on the imaging process. However, test runs of ISO bitstream image creation confirmed that ISO images may not

⁶⁶ Ibid

⁶⁷ Library of Congress, National Digital Information Infrastructure and Preservation Program (NDIIP). 2015. "ISO Disk Image File Format." *Sustainability of Digital Formats: Planning for Library of Congress Collections*. Accessed April 8. <http://www.digitalpreservation.gov/formats/fdd/fdd000348.shtml>.

⁶⁸ Digital/Latent Evidence Forensic Scientist Manager. 2013. "Technical Procedure for Removable / External Media Imaging, Version 3". Digital/Latent Evidence Section, North Carolina Department of Justice. <http://www.ncdoj.gov/getdoc/ee75fa76-eb75-4246-84a3-c04aeb954ba7/Computer-Removable-External-Media-Imaging-10-31-20.aspx>.

⁶⁹ See discussion on the Bitcurator Users Forum list

⁷⁰ "CDRDAO Homepage." 2015. Accessed April 14. <http://cdrdao.sourceforge.net/>.

⁷¹ Woods, Kam, and Geoffrey Brown. 2009. "From Imaging to Access - Effective Preservation of Legacy Removable Media." In *Society for Imaging Science and Technology*, 213–18. Springfield, VA: Society for Imaging Science and Technology.

⁷² "DD - ForensicsWiki." 2015. *ForensicsWiki*. Accessed April 14. <http://www.forensicswiki.org/wiki/Dd>.

⁷³ "DCFLDD." 2015. Accessed April 14. <http://dcfldd.sourceforge.net/>.

⁷⁴ "Ddrescue - GNU Project - Free Software Foundation (FSF)." 2015. Accessed April 14. <https://www.gnu.org/software/ddrescue/>.

⁷⁵ Cue Sheet (computing) - Wikipedia, the Free Encyclopedia." 2015. Accessed April 21. http://en.wikipedia.org/wiki/Cue_sheet_%28computing%29.

be the appropriate solution for all optical media imaging, particularly not for mixed mode disks and DVDs. It was also interesting to note that irrespective of imaging a CD-R, CD-RW or DVD the metadata file generated in FTK Imager documented the source disk as being a CD-ROM. All of the disks imaged also included filesystems in addition to ISO9660 such as JOLIET and UDF. In some cases there were more than one filesystem on the same disk. I also encountered problems when trying to image a DVD-R. To begin with the disk contained two different file systems – ISO9660 and UDF. FTK Imager only provided the option to image the UDF file system. This resulted in two ISO files (ISO1 and ISO2), as well as a disk image file, an image summary and a CUE file.

FTK Imager also provides options for saving the logical contents of optical media only. Again, the testing process generated 3 files: an AD1 image file, a text file containing basic imaging metadata and a CSV file consisting of filenames, paths, file sizes, dates of creation, modification and access, and stored hash values. It seems apparent that logical images will not be appropriate for optical media that contain more than straightforward data files.

All of this means that while FTK Imager has the capacity to image optical media, there was not much success when testing the process for mainly mixed mode, multi session and multiple file system disks. While it looks like a promising option, there is more that needs to be figured out.

Optical media in the Altman and Sayles collections

The Altman collection consists of 3 Kodak Photo CDs (1800MB total), 46 CD/CD-Rs (16.5GB total) and 2 DVD-Rs (9.4GB total). There are a total of 128 CD varieties (87GB total) in the John Sayles collection, and 47 DVDs / DVD-Rs (260GB total).

The identified problems, and different options for optical media imaging need to be weighed up against the actual characteristics of the optical media in the Altman and Sayles collections as imaging may or may not be the technically appropriate solution in all instances.

Hard drives

Hard drive imaging

Hard disk drives are typically available as one of three interfaces – Small Computer System Interface (SCSI), Integrated Drive Electronics (IDE), and Serial ATA (SATA). There is also eSATA, which is used for external drives⁷⁶.

Hard drive imaging both increases the need for adequate storage space, and will help to determine what is needed for the storage and memory capabilities of the host workstation/s. When disk images are compressed, they can be one-half to one-sixth of the size of the source media⁷⁷.

⁷⁶ “A Practical Guide to Computer Forensics Investigations > Chapter 3. Handling Computer Hardware > Hard Disk Drives : Safari Books Online.” 2015. Accessed June 3. <http://proquest.safaribooksonline.com/book/networking/forensic-analysis/9780132756174/chapter-3dot-handling-computer-hardware/ch03lev1sec1.html#X2ludGVybmFsX0h0bWxWaWV3P3htbGlkPTk3ODAxMzI3NTYxNzQlMkZjaDAzbGV2MXNIYzJfaHRtbCZxdWVyeT0=>.

⁷⁷ Woods, Kam, Christopher A. Lee, and Simson Garfinkel. n.d. “Extending Digital Repository Architectures to Support Disk Image Preservation and Access.” <http://www.ils.unc.edu/calleep/p57-woods.pdf>.

Before proceeding with imaging a hard drive, it is essential to ensure that the appropriate hard drive write blockers are connected and enabled. Proper connection of write blockers will entail the following basic steps:

- Identify the right signal and power cables to use
- Connect the hard drive to the appropriate write blocker port (could be SATA or IDE, or in the case of external FireWire drives could be FireWire port, or in the case of external hard drives with USB connectors could be USB2.0 or 3.0 port (in some cases it may be necessary to use adapters – in the case of laptops)
- Connect the hard drive to the write blocker’s DC out using the correct power cable
- Connect the write blocker to the forensic workstation
- Ensure all connections are correctly made
- Plug in write blocker, ensuring ‘DC in’ light is lit
- Turn the power on – the workstation will recognize the hard drive and the Host Detect LED on the write blocker should light up
- Then proceed to imaging⁷⁸⁷⁹

There are also specific instructions for connecting Apple computers, and for imaging Apple computers in target disk mode. This is a special boot mode in which the computer boots up into a mode where it emulates a FireWire storage device. This means that imaging can be done without having to disassemble the computer, and using the same processes and tools as for a FireWire drive⁸⁰.

Both Bitcurator and FTK Imager are equipped for hard drive imaging. A noted issue with Bitcurator has been its lack of support for the exFAT file system which is used by some external hard drives to support interoperability between Windows and Mac OS X platforms. In this case, FTK Imager is the recommended software option⁸¹.

Hard drives in the Altman and Sayles Collections

There are three FireWire drives in the Altman collection of 250GB each. In the Sayles collection there is a 3TB Porsche design desktop drive.

The forensic workstation at Buhr currently includes a Tableau T9 forensic FireWire bridge to support the imaging of the FireWire drives in the Altman collection, and a Tableau T8-R2 to facilitate imaging of USB external hard drives and pen drives such as the Porsche design desktop drive in the Sayles collection.

Issues with hard drive imaging

Imaging hard drives present some challenges for identifying and possibly redacting sensitive, confidential or restricted content. This content may include social security numbers, financial information, medical records, copyrighted content, content not included in the donor/purchase agreement, and research data

⁷⁸ Hull History Centre. n.d. “Idiot Guide No. 3: FTK Imager.”
<http://www.hullhistorycentre.org.uk/discover/pdf/Idiot's%20Guide%20-%20FTK%20Imager.pdf>.

⁷⁹ “Tableau T9 Forensic FireWire Bridge: Users Manual.” 2009. Tableau.

⁸⁰ “Tableau T9 Forensic FireWire Bridge: Users Manual.” 2009. Tableau.
https://www.digitalintelligence.com/files/UltraBlockFirewire_Manual.pdf.

⁸¹ “Getting to Know FRED: Introducing Workflows for Born-Digital Content | Practical Technology for Archives.” 2015. Accessed June 2. http://practicaltechnologyforarchives.org/issue4_prael_wickner/.

where participants are identifiable. It may also include deleted disk sectors containing this kind of content. This does not only apply to hard drives, but the need to adequately protect sensitive data becomes more significant when dealing with large volumes of data on a disk. If possible, these issues need to be addressed during the acquisition process⁸². However, since this is not always possible for born digital materials, an essential feature of post-imaging analysis would be to apply tools and methods for identifying, extracting, or anonymizing sensitive content. Some tools include:

- Identity Finder: <http://www.identityfinder.com>
- The Forensic Toolkit (FTK) by Access Data: <http://www.accessdata.com> (not free, may be costly)
- Fiwalk (incorporated into Bitcurator)
- BulkExtractor: http://www.forensicswiki.org/wiki/Bulk_extractor (incorporated into Bitcurator)
- EnCase by Guidance Software: <http://www.guidancesoftware.com> (proprietary)
- Firefly: <http://www.cites.illinois.edu/ssnprogram/firefly/index.html> -- a free tool created by the University of Illinois Urbana-Champaign to find social security numbers⁸³.

The Bitcurator approach to this issue has been to image first and ask questions later. Another approach has been to at least protect deleted disk sectors by saving images as logical rather than forensic images. In both of these cases, an appraisal policy for born-digital media would provide useful directives.

Metadata

Three levels of metadata are generated during the imaging and analysis process – the metadata that records details of the imaging process (including hash values and image validation), the file and file system inventory (including file and filesystem validation), and related or derived metadata (descriptive)⁸⁴.

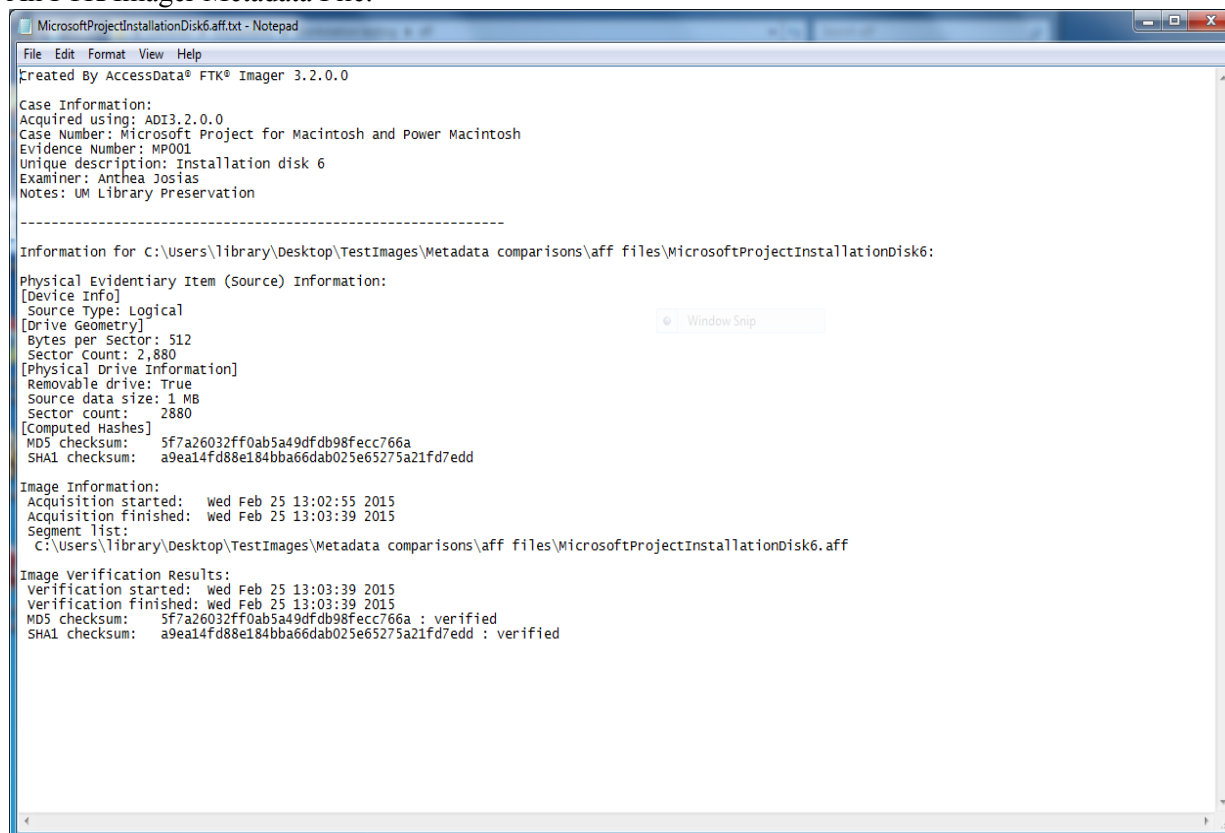
In both Bitcurator and FTK Imager, the administrative and technical metadata captured during the imaging process includes a case or accession number, name of the person creating the image, image creation date, hash values, and other information as per the diagrams below. This includes examiner-inputted administrative metadata, as well as automatically-generated technical metadata. There is a need to decide which metadata would be important, and to map these to existing metadata schemas.

⁸² Redwine, Gabriela, Megan Barnard, Kate Donovan, Erika Farr, Michael Forstrom, Will Hansen, Jeremy Leighton, Nancy Kuhl, Seth Shaw, and Susan Thomas. 2013. "Born Digital: Guidance for Donors, Dealers, and Archival Repositories". CLIR Publication No. 159. Washington, DC: Council on Library and Information Resources. <http://www.clir.org/pubs/reports/pub159/pub159.pdf>.

⁸³ Barrera-Gomez, Julianna, and Ricky Erway. 2013. *Walk This Way: Detailed Steps for Transferring Born-Digital Content from Media You Can Read In-House*. Dublin, Ohio: OCLC. <http://oclc.org/content/dam/research/publications/library/2013/2013-02.pdf>.

⁸⁴ Woods, Kam, Christopher A. Lee, and Simson Garfinkel. n.d. "Extending Digital Repository Architectures to Support Disk Image Preservation and Access." <http://www.ils.unc.edu/callee/p57-woods.pdf>

An FTK Imager Metadata File:



```
MicrosoftProjectInstallationDisk6.aff.txt - Notepad
File Edit Format View Help
Created By AccessData® FTK® Imager 3.2.0.0

Case Information:
Acquired using: ADI3.2.0.0
Case Number: Microsoft Project for Macintosh and Power Macintosh
Evidence Number: MP001
Unique description: Installation disk 6
Examiner: Anthea Josias
Notes: UM Library Preservation

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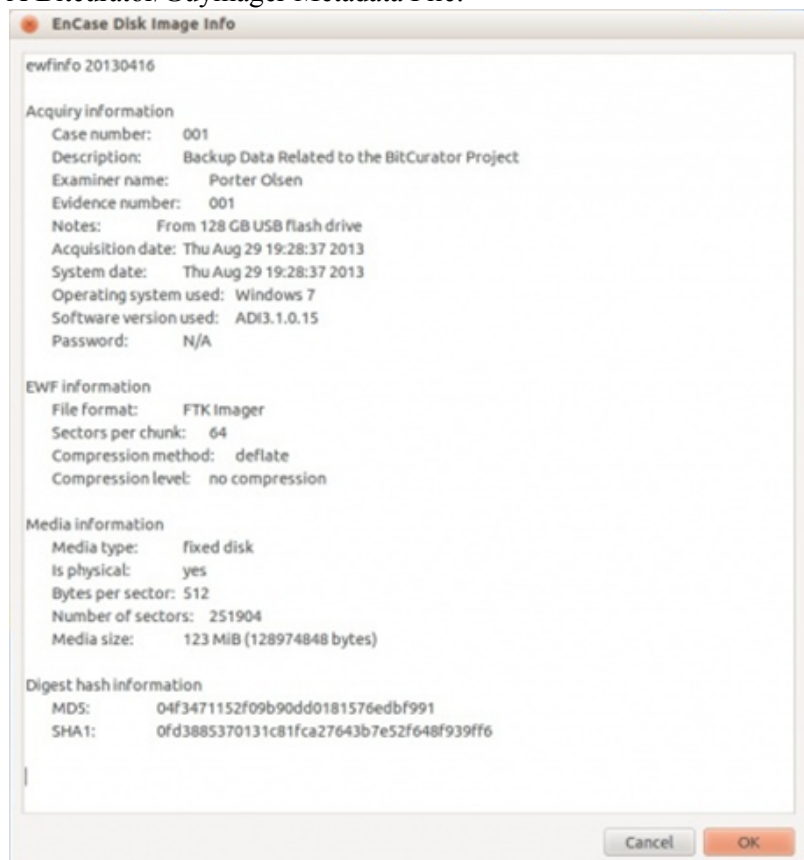
Information for C:\Users\library\Desktop\TestImages\Metadata comparisons\aff files\MicrosoftProjectInstallationDisk6:

Physical Evidentiary Item (Source) Information:
[Device Info]
Source Type: Logical
[Drive Geometry]
Bytes per Sector: 512
Sector Count: 2,880
[Physical Drive Information]
Removable drive: True
Source data size: 1 MB
Sector count: 2880
[Computed Hashes]
MD5 checksum: 5f7a26032ff0ab5a49dfdb98f66a
SHA1 checksum: a9ea14fd88e184bba66dab025e65275a21fd7edd

Image Information:
Acquisition started: wed Feb 25 13:02:55 2015
Acquisition finished: wed Feb 25 13:03:39 2015
Segment list:
c:\Users\library\Desktop\TestImages\Metadata comparisons\aff files\MicrosoftProjectInstallationDisk6.aff

Image Verification Results:
Verification started: wed Feb 25 13:03:39 2015
Verification finished: wed Feb 25 13:03:39 2015
MD5 checksum: 5f7a26032ff0ab5a49dfdb98f66a : verified
SHA1 checksum: a9ea14fd88e184bba66dab025e65275a21fd7edd : verified
```


A Bitcurator/Guymager Metadata File:



Important issues for consideration include which fields (in FTK Imager and Guymager) are used to record which metadata, and the formats in which this metadata is recorded. One important example is how persistent identifiers (PIDs) are allocated, and recorded. In addition to ensuring that PIDs are unique, they also need to enable future interoperability. Some common PID schemes include ARK, DOI, Handle, PURL, URI, URL and URN⁸⁵.

Tools to assist in metadata recording and extraction during the imaging and file level analysis processes include:

- Karens Directory Printer
- Fiwalk
- FTK Imager
- NARA File Analyzer and Metadata Harvester⁸⁶

⁸⁵ "Paradigm | Workbook on Digital Private Papers | Administrative and Preservation Metadata | Persistent Identifiers." 2015. Accessed June 16. <http://www.paradigm.ac.uk/workbook/metadata/pids-schemes.html>.

⁸⁶ Barrera-Gomez, Julianna, and Ricky Erway. 2013. *Walk This Way: Detailed Steps for Transferring Born-Digital Content from Media You Can Read In-House*. Dublin, Ohio: OCLC. <http://oclc.org/content/dam/research/publications/library/2013/2013-02.pdf>.

CONCLUSION

While this report has focused most particularly on floppy disks, optical media and hard drives the same principles can be applied when considering the imaging of different kinds of media. Some basic fundamental issues are addressed, and a need to understand specific media requirements in terms of hardware and physical composition is highlighted.

Some identified next steps for consideration would include:

- Working with individual files and file formats: develop file format action plan. In addition to looking at the Deep Blue Preservation and Format Support Policy. (<http://deepblue.lib.umich.edu/static/about/deepbluepreservation.html>) also look at the Florida Digital Archive File Preservation Strategies by Format (http://fclaweb.fcla.edu/fda_format_landing_page), which includes format specific metadata.
- Develop appraisal guidelines, as appropriate at different stages of born digital media processing. These would include an approach to working with sensitive / confidential / copyrighted content.
- Improve the capacity of the workstation to implement imaging.
- Access to files, using programs such as QuickView Plus, in combination with the finding aid or other access tools.
- Metadata standardization and workflow.

APPENDICES

Notes on Media in the Altman and Sayles Collections

MEDIA	NOTES
8" floppy	<ul style="list-style-type: none">• Have to use a PC that can handle high density drives.• 8" diskettes were supported by MS-DOS ver 1.25 and 2.0, and predecessor 86-DOS around 1980.• Likely candidates for outsourcing, but outsourcing options are limited, at this point non-existent.• Possible to source readers on ebay, with no guarentees of whether they would work.• These disks may have to be considered as a lower priority because of the technical challenges.
5.25" floppy	<ul style="list-style-type: none">• Would be important to have more than one reader at hand, including drives to read both Mac and PC-formatted disks.
3.5" floppy	<ul style="list-style-type: none">• Many of the 3.5" floppy disks are formatted for Mac.• In addition to the generic 1.4 MB disks, the Altman collection contains 50+ 800k and 400k disks. One or more external Mac 800k drives (backwards compatible) would therefore need to be sourced, and used in tandem with the Kryoflux floppy controller.
Zip disks	<ul style="list-style-type: none">• More than half of the zip disks in the Altman collection are formatted for Mac.

MEDIA	NOTES
	<ul style="list-style-type: none"> • The download link for Iomegaware is no longer active, but the software may still be available from https://lenovo-na-en.custhelp.com/app/subproduct/p/1039. • There may be some challenges with using zip disks across platforms. According to the Iomega website, <ul style="list-style-type: none"> ○ You can use PC-formatted disks on a Mac OS system that has File Exchange 3.0 or higher installed. It is recommended that you use PC-formatted Zip disks for file transfer only. ○ PC systems cannot read a Mac-formatted Zip disk unless special software is installed on the system. If you try to use a Mac-formatted Zip disk on a PC that does not have disk exchange software installed, you will see a message indicating that the disk is not formatted. ○ If you need to transfer files between a PC and a Mac, you can use a PC-formatted Zip disk if File Exchange 3.0 or higher is loaded on the Mac. You can use a Mac-formatted Zip disk if the PC has disk exchange software installed. ○ Formatting zip disks erases all data on the disks, so one should not attempt to format any of the disks • Iomega Zip250 drives are backward compatible (price range is between \$80 and \$150). • Iomega zip and jaz drives have a “click of death” problem that can sometimes result in irreparable data loss.
Jaz disks	<ul style="list-style-type: none"> • 2 / 3 disks formatted for Mac, while one is IBM-formatted. • Jaz disks should be write-protected using Iomegaware. • For instructions on how to write-protect jaz disks for Mac and Windows platforms, see the Iomega online support manual. • Jaz disks can be copied using the Iomega CopyDisk tool. • Iomegaware is used to eject jaz disks. • Iomegaware may be downloadable from Lenovo, at https://lenovo-na-en.custhelp.com/app/subproduct/p/1039. • As with zip disks, there are some challenges with using jaz disks across platforms. According to the Iomega website, <ul style="list-style-type: none"> ○ You can use PC-formatted disks on a Mac OS system that has File Exchange 3.0 or higher installed. It is recommended that you use PC-formatted Jaz disks for file transfer only. ○ PC systems cannot read a Mac formatted jaz disk unless special software is installed on the system. If you try to use a Mac-formatted Jaz disk on a PC that does not have disk exchange software installed, you will see a message indicating that the disk is not formatted. ○ If you need to transfer files between a Mac and a PC, you can use a PC-formatted Jaz disk if the PC has disk exchange software installed. • Can be read on an Iomega portable SCSI 2GB Jaz drive (price range is between \$70 - \$150). • Will also require a SCSI to USB cable, or a Jaz traveller adapter to connect the jaz drive to a parallel port. • Requires Iomegaware 4.0.2. • Iomega zip and jaz drives have a “click of death” problem that can sometimes result in irreparable data loss.
Syquest removable hard disk	<ul style="list-style-type: none"> • On the market from 1993 – 1998. • The Altman inventory notes the likelihood of a SQ 3105 drive / SQ310 cartridge, and that the disks are in a snap-shut plastic case.

MEDIA	NOTES
	<ul style="list-style-type: none"> • Two possibilities for Syquest drives: SQ3105 drive/SQ310 (105 MB), or the SQ3270/SQ327 (270 MB). • The 105 MB disks are compatible with the 270MB drives, but they are not compatible with any other Syquest disk formats • 105 MB disks are 3.5 inch cartridge formats. • Syquest was purely a Mac-based technology. • SCSI adapter would be necessary for connecting Syquest drive to PC.
DDS-2	<ul style="list-style-type: none"> • HP DDS-2 tape drive • DDS drives are backwards compatible. • Drives that should work are: HP Surestore/Storage Works DAT8 (write/read); HP Surestore/Storage Works DAT 24/24x6 (write/read); HP Storage Works DAT40 Hotplug (write/read); HP Surestore/Storage Works DAT40/40x6 (write/read); HP Storage Works DAT24 USB (write/read); HP Storage Works DAT40 USB (write/read)⁸⁷.
8mm AIT	<ul style="list-style-type: none"> • It seems that a Sony AIT1 external tape drive would be needed to access these disks
Kodak Photo CD	<ul style="list-style-type: none"> • Use freeware such as Irfanview to extract files from the Photo CDs (http://www.irfanview.com). Irfanview has batch mode. • Extract high resolution image (16 base version) as uncompressed tiff (preservation version). • Use Photoshop to create jpeg derivative from tiff. • See PhotoCD wikipedia page, http://en.wikipedia.org/wiki/Photo_CD, for more information.
CD/CD-R/DVD/DVD-R	<ul style="list-style-type: none"> • Question of whether to create an image, or simply just extract the files on the disks.
External hard drives	<ul style="list-style-type: none"> • Bitcurator imaging instructions for external hard drives are available at http://wiki.bitcurator.net/index.php?title=Creating_a_Disk_Image_Using_Guymager. • FTK instructions for imaging hard drives are available at http://www.hullhistorycentre.org.uk/discover/pdf/Idiot%27s%20Guide%20-%20FTK%20Imager.pdf. • Make sure to safely eject the write blocker when imaging is completed, using the “Safely Remove Hardware” utility before switching off or removing the write blocker. • When compressed, modern disk images are typically one half to one sixth of the source media. Therefore imaging a 250GB laptop hard drive would result in a digital file between 50 - 150 GB.

⁸⁷ “HP StorageWorks DDS/DAT Media - DDS/DAT Media Compatibility Matrix.” 2015. Accessed June 16. http://h20564.www2.hp.com/hpsc/doc/public/display?docId=emr_na-lpg50457.

Notes on hardware

	Hardware	Use for	Price est.	Notes
Floppy Drive Controllers	Device Side FC5025	5.25" floppy disks	\$55	<ul style="list-style-type: none"> • Software included in purchase • Works with Linux x86 2.6.24, Mac OS x PPC 10.4.11, Mac OS X Intel 10.6.4, Windows XP SP3 32-bit, Windows 7 (32/64-bit) • MITH Vintage Computer site includes a step-by-step guide to installation and use
	Kryoflux controller	5.25" floppy disks, 3.5" disks (all formats), 8" disks, 3" disks	\$160 for hardware Software license in excess of \$3000	<ul style="list-style-type: none"> • Highly recommended • Most platforms supported • Includes built-in write protection • Works with Windows XP, Vista (32-bit), Windows 7 (32/64-bit), Mac OS X, Linux • Can be set to read "unreadable" sectors multiple times • Software acquisition is not a prerequisite in Bitcurator
	Catweasel controller	5.25" floppy disks, 3.5" disks (all formats), 8" disks	\$130	<ul style="list-style-type: none"> • Seems to have been discontinued
				•

Appraisal notes:

Takes place at different stages of processing born-digital media

- initial content appraisal: does content align with collecting interests; potential use of the collection, or access restrictions; obtain as much contextual information as possible; do items hold cultural or research value
- assess if there are privacy concerns
- assessment of condition of digital files (what to do with damaged files, or damaged media)
- are files duplicated elsewhere
- relationship with paper materials in the collection
- detailed assessment of file formats
- are there extraordinary preservation challenges
- follow guidelines on retention and disposition

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