The Archivist's Guide to KryoFlux

Editor's Note:

The Archivist's Guide to KryoFlux aims to provide a comprehensive resource for practitioners working with born-digital materials in an archival context. **This DRAFT of the Guide is now closed for for comments and contributions from the digital archives community.** *The authors are currently working to incorporate revisions and put together a final draft of the document, which will be freely available on GitHub circa March 2018. You can get in touch with the authors by emailing* archivistsguidetokryoflux@gmail.com.

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About this guide:

For archivists working with aging floppy disks, the KryoFlux can be an incredibly powerful tool. It is not, however, an incredibly user-friendly one. Scant documentation and a somewhat advanced user forum have caused frustration for many archivists and, in some cases, hampered use. Having heard such complaints at conferences and meetings across the country, our group of digital archivists and graduate students from Duke, Emory, UCLA, the University of Texas, and Yale decided to develop this user guide, which has been written specifically with the needs of archivists in mind.

We've assumed that readers are already familiar with the principles underlying digital forensics and its application in an archival context, but do not assume readers to have any previous experience with the KryoFlux. A key feature of this guide is that we do not intend or expect that it be read in any particular order. Instead, we hope that users will move between sections as they are most relevant and useful.

The user guide is divided into two parts:

- **Part one** provides step-by-step instructions designed to get you set up and started. You may wish to start here if you already have a KryoFlux in hand and are ready to jump in. We've included links to relevant sections in part two so you can dip in and out as needed.
- **Part two** provides a more in-depth introduction to the KryoFlux and floppy disks as a medium for data storage. You may wish to start here if you are interested in learning more about the ins and outs of how the KryoFlux works before diving in, or if you're weighing the benefits of purchasing a KryoFlux for your institution.

This is an unofficial guide and has not been written in affiliation with the Software Preservation Society (SPS). The official KryoFlux manual is available at http://www.kryoflux.com/download/kryoflux_manual.pdf.

Introduction to the KryoFlux:

The KryoFlux is a floppy disk controller card developed by the Software Preservation Society that can read a wide variety of legacy floppy disks and create bit-for-bit disk images of their contents. Purchase of the KryoFlux hardware typically includes the controller board, a 3.5" floppy disk drive, the KryoFlux software, and any necessary cables, although the exact contents will vary depending on the package selected for purchase. The KryoFlux is available to buy at the KryoFlux website, where institutions may choose from a range of "pro" packages depending on their needs. An institutional license is required and is included with every order of a pro package hardware kit. This results in a cost that, while not huge, is also not insignificant. Because costs vary depending on institution size and may change over time, it is difficult to provide an estimated range here. However, institutions can contact the KryoFlux team for more information about pricing.

The KryoFlux has several features that differentiate it from an external USB floppy disk drive:

- **Supports a wide variety of encoding formats:** Data stored on a floppy disk is encoded using one of a number of available formats. The KryoFlux supports a wide variety of floppy disk encoding formats and can help users identify the correct one. During disk imaging, the KryoFlux software reports the degree to which image capture has been successful.
- **Generates stream files where the encoding format is unknown or unsupported:** In cases when the encoding format is unknown or unsupported, the KryoFlux can read the magnetic flux that represents data stored on a floppy disk and store it as raw stream files. This can also be a useful feature if disks are copy-protected. This allows users to capture an image of data stored on any disk, regardless of format. That said,

the KryoFlux's stream file format is proprietary and cannot be rendered. As such, it offers a temporary solution to unknown or unsupported formats, but is not considered ideal for preservation purposes.

- **Creates disk images from stream files:** This process is called "deviceless mode." Deviceless mode allows for the creation of multiple images, without having to physically image a disk again, by using stream files. This way, it is possible to try multiple file systems out on the same set of stream files.
- **Effectively handles degraded data:** There are several ways that floppy disks can become difficult or impossible to read, all of which tend to occur within 10-20 years. Magnetic storage is vulnerable to wear, and the adhesive keeping the magnetic coating in place can degrade, resulting in data loss. In addition, contaminants can stick to the magnetic storage and damage it. Floppy disks can also demagnetize over time due to changes in temperature or magnetic fields near the disk. The KryoFlux has a better rate of success than external USB floppy drives at imaging disks that have undergone this kind of damage.
- **Includes built-in write-blocking functionality:** Users can enable a write-blocker on the KryoFlux board to ensure a one-way information flow, removing the need for extra write-blocking hardware.

Example:

Emory University's Stuart A. Rose Manuscript, Archives, and Rare Book Library (formally, MARBL) experimented with a range of imaging methods, including the KryoFlux, in order to process thirty-seven 3.5" floppy disks included among the papers of writer and activist Alice Walker. The integrated setup of the KryoFlux allowed for an OS- and file system-agnostic approach that allowed for the identification and imaging of a wide variety of disks in various states of degradation. An article in the June 2014 issue of *Practical Technology for Archives* describes the project in greater detail.

PART ONE: Getting started

SETUP AND INSTALLATION

What's in the box?

The KryoFlux setup consists of several pieces of hardware connected by cables (see figure 1). Because the KryoFlux board is so small and light, the setup can be a little precarious once connected. It also takes up more space than it does when boxed, so be sure that you have enough desk space to accommodate the various components. When moving hardware, handle it with caution, and have someone else help move the components as needed. As always when working with sensitive electronic components, take steps to protect against static electricity by using an anti-static mat or anti-static wristband; always place the KryoFlux board on a non-conductive surface while it is in use.
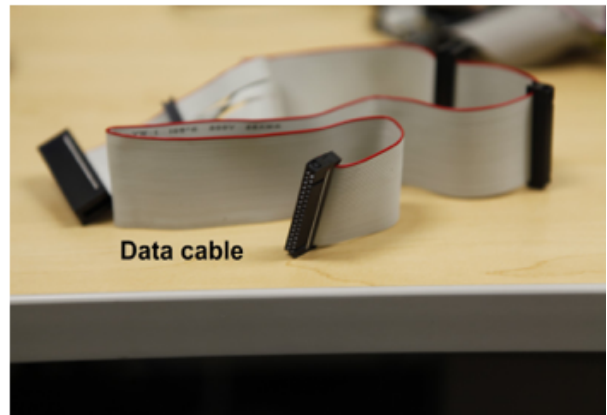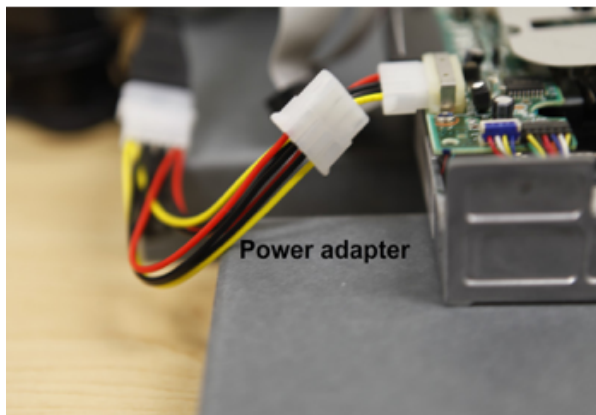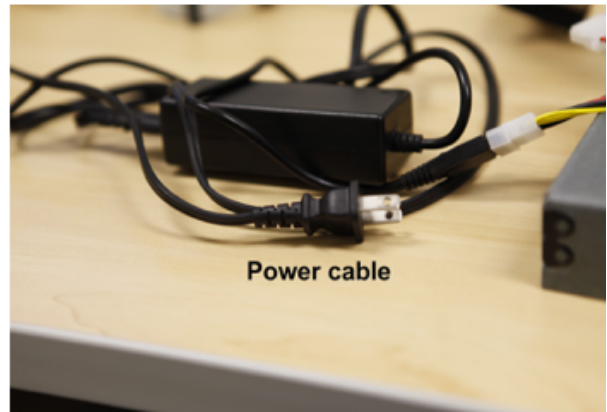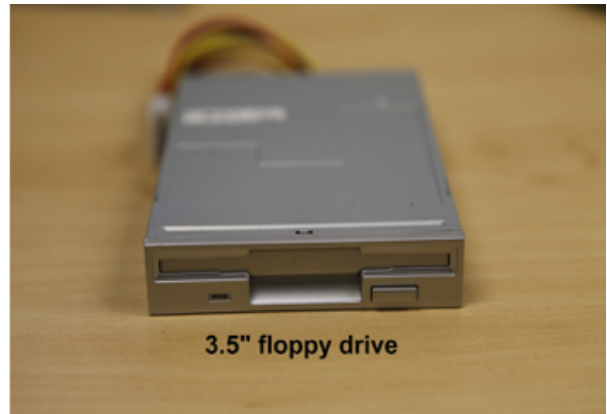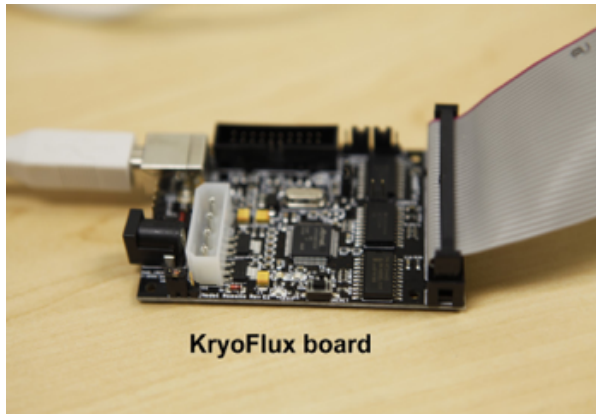
Figure 1: The various components included in the KryoFlux package. Depending on the package purchased by your institution, your box may also include a second backup KryoFlux board or a 5.25" floppy disk drive.

Downloading the software:

1. Download the directory containing KryoFlux driver and DTC files from the KryoFlux website: http://kryoflux.com/?page=download.

2. Save the directory to your chosen location. Make a note of this location (for example, C:\Users\Public\Desktop\kryoflux_2.51_windows).

1. Download the JDK Java Runtime Platform files from the Oracle website: http://www.oracle.com/technetwork/java/javase/downloads/jdk8-downloads-2133151.html.

2. Run the JDK dmg file (it will have a name similar to this: jdk-8ku121-macosx-x64.dmg).

3. Download the KryoFlux software from the KryoFlux website: http://kryoflux.com/?page=download.

4. Save the downloaded KryoFlux file to your chosen location. Make a note of this location (MacOSX will place the download in the following path by default, ~/Downloads/kryoflux_2.62_macosx).

5. Unzip the downloaded file and navigate to the dtc folder.

6. Install DTC:
   a. Double-click KryoFlux.mpkg (see figure 2);
   b. Follow prompts to install the software.
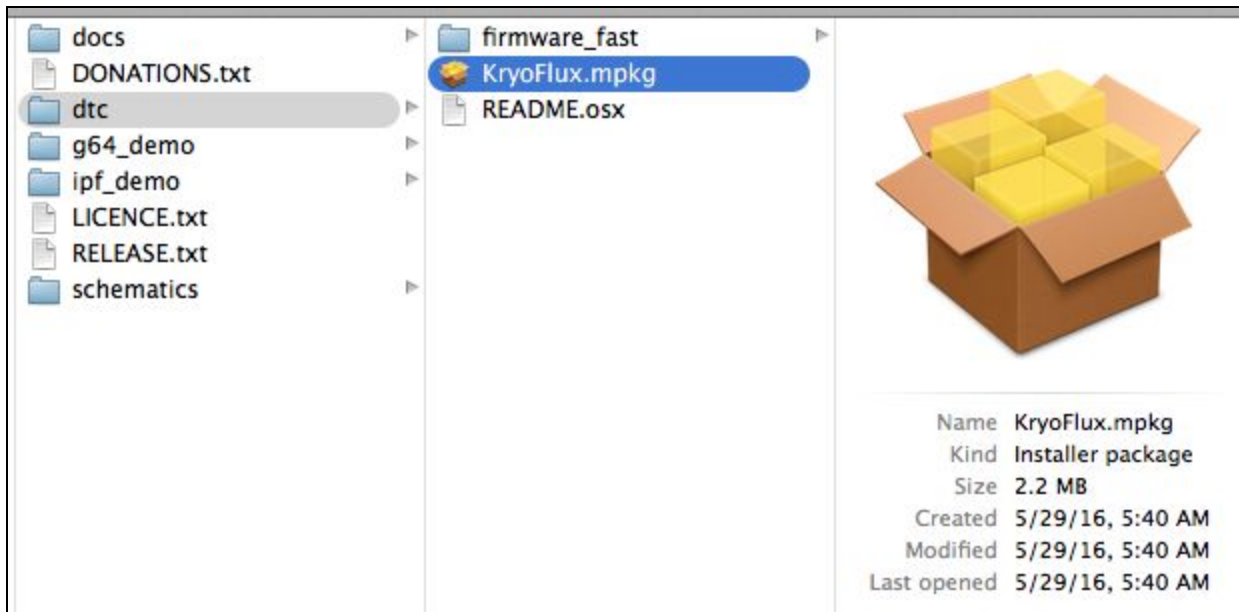
Figure 2: If using MacOSX, double-click KryoFlux.mpkg to install DTC.

NOTE: You will need administrator rights to the computer to install the package.

NOTE: If you receive an unidentified developer warning (see figure 3) when trying to install the package, right click on the package and choose "Open" from the menu and then choose "Open" from the pop-up window.

Figure 3: The unidentified developer MacOSX warning.

USING LINUX…

1. Download the Linux .tar file containing KryoFlux driver and DTC files from the KryoFlux website: http://kryoflux.com/?page=download

2. Save the .tar file and then use Archive Manager to extract the directory to your chosen location. Make a note of this location (for example, ~/Downloads/kryoflux_2.6_linux).

3. Launch a terminal window.

4. In the terminal window, type the following three commands (each followed by the *Enter* key) to install libusb and the JDK Java Runtime Platform:
   ```
   sudo apt-get install libusb-1.0-0-dev
   sudo apt-get install libusb-dev
   sudo apt-get install openjdk-7-jre
   ```
   If they are already installed, the system will tell you that your version is up to date.

USING LINUX: PREREQUISITES AND DEPENDENCIES

UDEV RULE

If this is your first time installing the KryoFlux software, you will also need to create a udev rule. The udev rule will prevent permissions errors as well as erasing the need for the user to root. (If this file is missing it is highly likely that the KryoFlux will not work properly.)

a. To create this rule, navigate to the following directory:
   ```
   /etc/udev/rules.d
   ```
b. While still in the above directory, create a file with the following title (use nano or a similar text editor):
   ```
   80-kryoflux.rules
   ```
c. Type the following text into the file:
   ```
   ACTION=="add", SUBSYSTEM=="usb", ATTR{idVendor}=="03eb",
   ATTR{idProduct}=="6124", GROUP="floppy", MODE="0660"
   ```

JAVA DEPENDENCY

The KryoFlux software relies on Java to launch the GUI. In some cases, even though Java was installed on the Ubuntu Linux workstation, archivists observed that the KryoFlux GUI did not call Java correctly when launching the GUI by clicking on "kryoflux-ui.jar." As a workaround, archivists at Princeton have developed a short bash script that invokes Java each time they launch the GUI. This script lives on the workstation's desktop and users click on it in order to start up the GUI in place of a desktop icon.

See also the Troubleshooting section for more information related to this issue.

Setting up the KryoFlux:

While it does not require an especially high level of technical skill, setting up the KryoFlux does demand some careful attention to detail.

Make sure to read this entire section before attempting to connect and power your board!

The floppy drive is an unstable source of power that can permanently damage the board, so it is imperative to follow the correct order when connecting/disconnecting KryoFlux.

If you suspect that you have a malfunctioning board or have damaged a board in the process of installing, and you have a backup board, do not use the backup board until you have successfully troubleshooted the original board. If you do not know why the original board is not working, you may inadvertently replicate the problem if you connect a backup board.

1. Always place the KryoFlux board on a non-conductive surface while it is in use. You may choose to use an anti-static mat or wristband, but typically this won't be necessary and there's debate about whether or not these types of anti-static devices will be helpful in a scenario like this one. NOTE: do not place the board on top of the anti-static bag in which the KryoFlux is shipped. The anti-static bags are conductive, and although the resistance is fairly high, it might cause data errors nonetheless.
2. Make sure the floppy disk drive is placed so that the spinning mechanism on its bottom side is not obstructed (i.e. on a raised surface that doesn't cover the bottom of the drive, such as bridging the drive across the space between two DVD cases).
3. Enable write-blocking functionality by removing the jumper for the write gate (see figure 4).
4. Connect the drive to the board via the data cable. Ensure that the data cable's first pin (the colored band) is oriented correctly. For more information about this, please see [Understanding Drive 1/0](#).
   a. For 3.5" drives, pin 1 must face left when the front of the drive is facing away from you. For some drives, this means that pin 1 will fact the outside of the drive when plugged in correctly, *but this is not always the case*. The rule of facing the drive away from you before plugging it in, and making sure that pin 1 faces left, should still be applicable to all 3.5" drives.
   b. For 5.25" drives, the same rule should apply. When the drive is facing away from you the first pin should be on the left.

c. On the KryoFlux side, the cable's first pin should be on the right if viewing the board with the cable connector closest to you (as in figure 5).
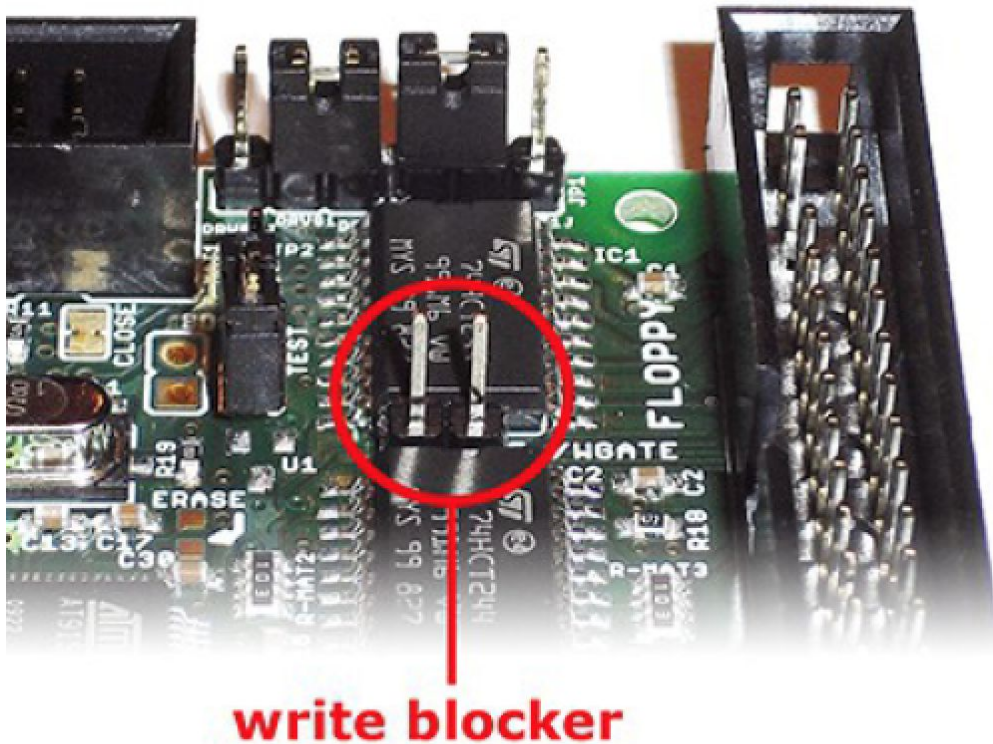
write blocker

Figure 4: Enable writeblocking functionality by removing the jumper for the write gate. This photograph shows the write gate once the jumper has been removed and writeblocking functionality enabled.

NOTE: If you are not familiar with the connectors on the data cable, the smaller ones connect to the board and to 3.5" drives, while the larger ones with gold lining connect to 5.25" drives.

5. Connect the KryoFlux board to the computer using the USB cable (see figure 5).

Figure 5: Once the drive is connected to the KryoFlux board via the data cable, connect the board to the computer using the USB cable.

NOTE: If using Windows, proceed to step 6. If using Mac or Linux, skip step 6 and proceed directly to step 7.

6. WINDOWS USERS ONLY (if using the KryoFlux on a Windows machine for the first time, you will need to complete step a. If, however, drivers are already installed, skip to step b):
    a. Install the KryoFlux drivers:
        i.   Launch the *Start* menu;
        ii.   Right-click on *Computer*;
        iii. Click *Properties*;
        iv.   Click *Device Manager*;
        v.   Right-click on *Unknown Device* in the Device Manager menu (see figure 6).
        vi.   Select *Browse my computer for driver software*. Depending on your institution's policies, you may need admin credentials starting with this step.

vii. Click *Browse* and navigate to the folder where the KryoFlux directory was saved in step 2.

viii. Select the KryoFlux directory and click *Next*.

ix. Click *OK* on all of the prompts to install the drivers.
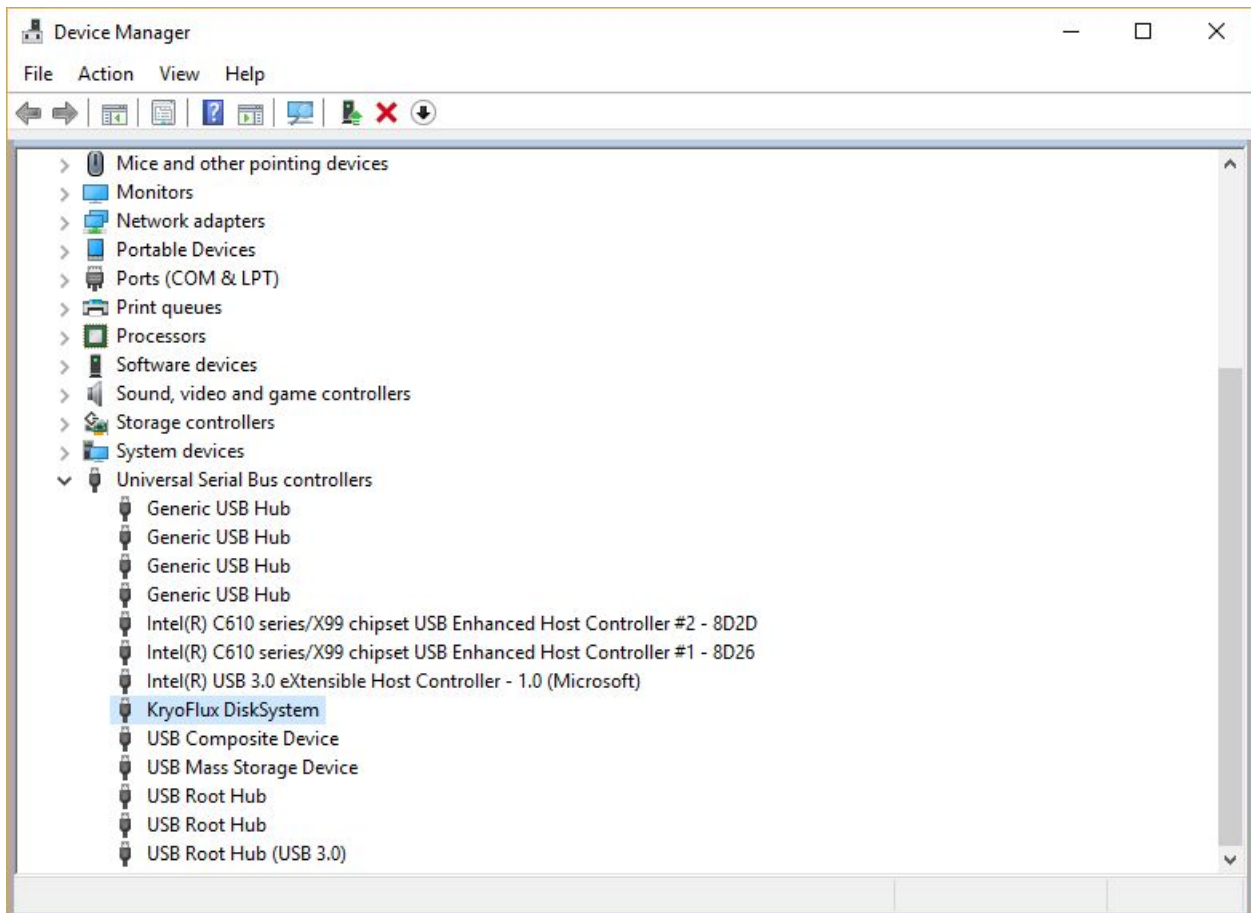
Figure 6: Device Manager. One of the devices in this menu will be labeled "Unknown Device." This is the KryoFlux. During installation, you may have to search through this list to find the "Unknown Device." Once the KryoFlux has been recognized, however, it should be listed under Universal Serial Bus controllers. The steps are largely the same in Windows 10, although the presentation is slightly different.

NOTE: See the troubleshooting section if you have trouble with this step, or if your Windows instance seems to have forgotten the drivers in between KryoFlux sessions.

b. Launch the command prompt: Go to the *Start* menu and type **command prompt** or **cmd** into the search box and hit *Enter*.

c. Using the command prompt, navigate to the dtc folder (located inside the KryoFlux directory downloaded at step 1) (see figure 7).

d. Type `dtc -c2` into the command prompt, and press *Enter*. If DTC gives an error message, this means it is working (it tried to install the driver, but the driver was already there, so DTC returned an error).

NOTE: Steps b through d may require admin credentials depending on your institution's setup.

USING THE COMMAND LINE:
- To switch between drives using the command line, type the drive letter followed by a colon and hit Enter.
    - *For example, navigate to C drive by typing* `c:` *and pressing* Enter (see figure 8).
- To move between folders, type `cd` followed by the path to the folder (cd stands for "change directory.")
    - *For example, navigate to the* Users *folder by typing* `cd Users` *and pressing* Enter.
- For an introduction to using the Windows command prompt, see The Programming Historian's Introduction to the Windows Command Line using Powershell or the Digital Citizen tutorial.

Figure 7

Figure 8: Navigate to C drive by typing c: and pressing enter.

7. Connect the floppy drive to the power. *This must be done last.*
   a. Plug one end of the power adapter into the power supply. The 4 3 2 1 on the power adapter plug is faint and hard to read, but the 4 3 2 1 on the power supply and adapter should align when plugging the power supply into the adapter.
   b. The other end is split and has two adaptor plugs. These plug into the floppy disk drive, *not* the KryoFlux board. The larger power adapter plug fits 5.25" floppy disk drives, while the smaller plug fits 3.5" floppy disk drives. You should <u>not</u> see a green light on the drive at this point. If the green light is on, the data cable has been connected to the drive backwards.

NOTE: Use care when handling the power adapter! The wires are not anchored well and will come loose if not handled gently. When connecting and disconnecting the adapter, try not to pull on the wires themselves--grip the plastic plug casing instead. With frequent handling, it's likely that the power adapter wires will come loose, but replacements are inexpensive.

   c. Finally, plug the power supply into an outlet.

NOTE: Because KryoFlux is based in Europe, you may need an adapter to plug the supplied

power cable into the Type A / B outlets used in America. If you don't have the appropriate adapter, the second half of a laptop or hard drive charger may work as a replacement for the second half of the power supply.

8. In a terminal window, navigate to the dtc folder located inside the KryoFlux directory downloaded at step 1 (see figure 7).
9. Insert a floppy disk into the floppy disk drive.
10. Type the following command into the terminal window:
    a. WINDOWS AND MAC USERS: `dtc -c2`
    b. LINUX USERS: `./dtc -c2`
11. Press *Enter*.

NOTE: DTC will find the maximum number of tracks available. A floppy disk typically stores data across 80 tracks, but some drives can access as many as 83.

You are now ready to start capturing disk images using the KryoFlux, either using the command line interface (CLI) or the graphical user interface (GUI).

Disconnecting the KryoFlux:

1. Disconnect the floppy drive's power supply.
2. Eject and disconnect the USB cable.
3. Disconnect the data cable/floppy drive cable.

Handling the KryoFlux:

GOOD: Tips for basic handling and care

Because it does not have a protective outer shell or cover, the KryoFlux board is fragile and vulnerable to damage. A good rule of thumb is to try to **handle it as little as possible** to avoid damage, and to **put the board away after you're done using it**--especially overnight or over the weekend--to prevent dust gathering.

Another thing to keep in mind is that the board is particularly vulnerable to changes in the electrical current. The most obvious precautionary measures you can take to protect your KryoFlux are:

1. **Plug its power supply into a surge protector**

2. **Always keep the KryoFlux away from conductive materials**, such as metal tabletops or other potential sources of static electricity.
3. **Place the KryoFlux on top of something non-conductive while in use**, such as a book, folder, or cardboard box. This material will act as a buffer so that you avoid accidentally putting the KryoFlux in direct contact with a conductive material. You may choose to use an anti-static mat or wristband, but typically this won't be necessary and there's debate about whether or not these types of anti-static devices will be helpful in a scenario like this one. NOTE: do not place the board on top of the anti-static bag in which the KryoFlux is shipped. The anti-static bags are conductive, and although the resistance is fairly high, it might cause data errors nonetheless.

BETTER: Creating an enclosure

In institutions where only one person will be working with the KryoFlux, it may be sufficient to handle the board carefully as described above. In cases when multiple staff members will be using the board, it will be much more challenging to monitor use to ensure careful handling.

Since the KryoFlux board is costly, you may want to look at simple enclosures. If your electronic acquisitions terminal is a commodity desktop tower or laptop computer, there is likely not going to be room in the housing to mount the board permanently. Archivists at Yale designed and wrote online about an enclosure they printed using a 3-D printer, and uploaded the design to [Thingiverse](#). It works relatively well, though there are a few caveats:

1. Depending on the 3D printer model available to you, a 3D print may have slight errors. One such enclosure printed with bits of additional polymer needed to be sanded down in order for the board to fit. At Emory, additional polymer supports, designed to help the enclosure maintain its shape during printing, later proved impossible to remove.
2. There are now variations on the original enclosure design. The original is a two-piece object and includes a base and a lid. A second version features a slide that may introduce additional complexity. Since 3D printing is iterative, you may want to experiment with designs until you find one that is right.
3. Though the enclosure is protective, it is still fairly small and both objects together do not weigh much. We make sure to store ours at the end of a session. We leave the ribbon cable attached to the board, and store the board in its enclosure in a slightly larger box along with the ribbon.

BEST: Installing KryoFlux in a computer tower

At Yale, the KryoFlux is installed internally in this dedicated disk imaging machine. The KryoFlux
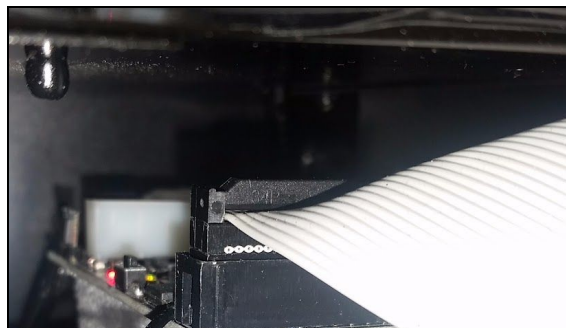
board is mounted to a disk shelf using zip ties to keep it from shifting inside the tower. A bit of foam is used between the kryoflux and the shelf as an insulator as well as preventing the board from scraping against the shelf. The first photo shows the USB cable from the front of the machine, the second photo shows the data cable attached through the back of the machine.
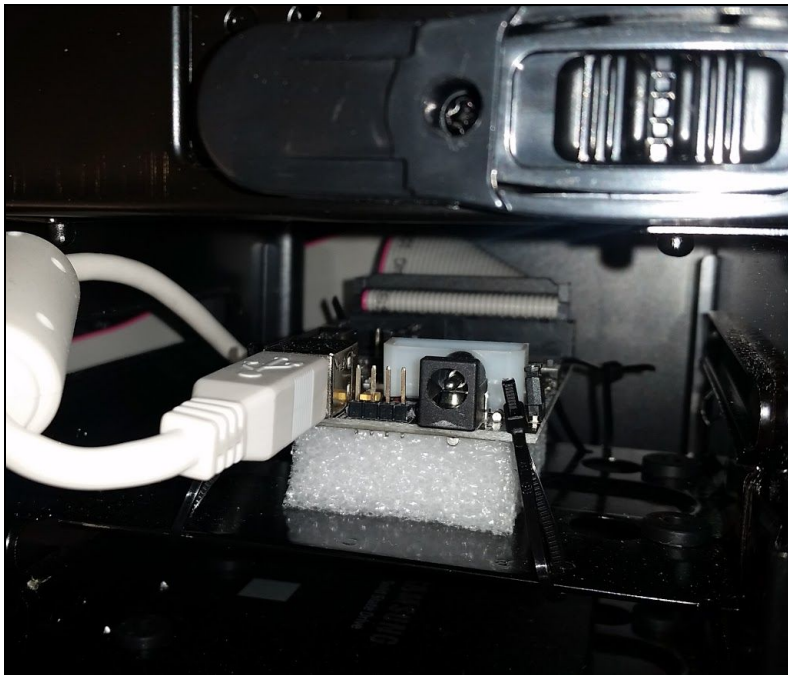
One note for future archivists attempting to internally install a KryoFlux: Be sure that the data cable is oriented correctly. In the photo below you can see that the data cable is twisted in order to correctly connect to both the KryoFlux board and the floppy disk drive. The correct orientation is dependent on the specific drive you are working with. See the set-up instructions for more information.
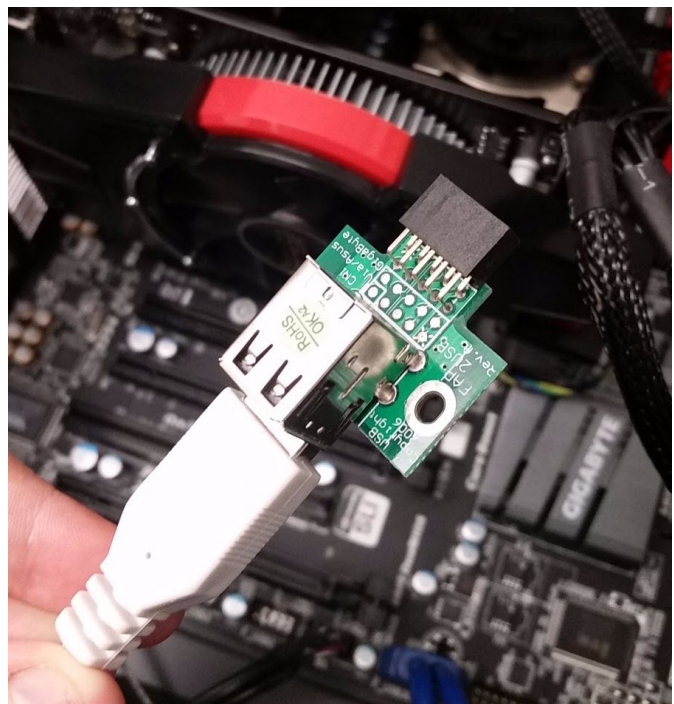
The USB cable is connected to an internal USB port on the motherboard. Some motherboards have USB ports installed; however, if your motherboard does not, you can purchase a USB header online for under ten dollars. This USB header connects to the motherboard to provide two internal USB ports. Shown here, the KryoFlux USB cable is connected to our USB header. The greatest advantage to having the KryoFlux board mounted in this way, is that it is difficult to knock a cord loose, but if someone needs to remove the board or check the connections, the board can be disconnected and removed fairly easily as seen here.

USING THE KRYOFLUX

GUI vs. CLI:

The Kryoflux's Disk Tool Console (DTC) is the command line application that sits underneath the Kryoflux's graphical user interface (GUI).

The KryoFlux provides two options for interacting with DTC:
1. Use the graphical user interface (GUI)
2. Run DTC using the command line interface (CLI)

Both provide similar functionality, and the writers of this guide do not endorse one approach over the other. Your decision as to which to use will likely depend in part on your own experience and personal preference. That said, the following summary provides an overview of some of the differences between the two.

Ease of use for beginners
THE WINNER: The GUI

As might be expected, the GUI provides a more intuitive interface and a lower barrier of entry to use. Its color-coded interface provides immediate and easily-interpreted feedback, allowing users to quickly determine whether imaging is likely to have been successful. It might be an obvious choice for those who are unfamiliar with the command line. Documentation about the GUI is more widely available and more accessible than its CLI counterpart, which tends to assume some existing knowledge of the command line.

Efficiency and flexibility

THE WINNER: The CLI

In terms of efficiency and flexibility, the CLI may just pip the GUI to the post--especially if you are imaging a large number of disks. Whereas changing a setting using the GUI might involve several clicks, changing a setting using the CLI only requires typing the relevant option in the command. It's a small difference, but may be enough to sway you towards the CLI if your aim is to get through as many disks as you can in the shortest possible time.

Similarly, use of the CLI also allows for the development of simple scripts that could run a series of commands with one keystroke--which you may or may not deem necessary, depending on your workflows. This does, of course, require some scripting expertise--but the opportunity to simplify imaging procedures may be motivation enough to start learning.

Finally, the number of options available using the CLI may provide more advanced users with added flexibility. The CLI, for example, allows greater control over what information is reported as part of the KryoFlux's log files.

Reporting

THE WINNER: The GUI

A particularly nice feature of the GUI are the visualizations that it provides as data is being imaged. Color-coded blocks provide immediate feedback on whether imaging has been successful. The use of red, orange, green, and grey blocks to represent bad, modified, good, and unrecognised data respectively is intuitive, and provides a quick and holistic overview for the user.

In the course of creating STREAM files, the GUI also provides visualizations of the flux data as a scatter plot graph and, if you're the sort of person who knows how to interpret flux data as represented in a scatter plot graph, these can help diagnose media or hardware problems—or so I've been told. If you're not the sort of person who knows how to interpret flux data as represented in a scatter plot graph, these can at least draw your attention to where problems might be lurking—even if you are not able to fully diagnose them (see Gough Lui's Project KryoFlux series of Blog posts for more information).

Command line output provides similar levels of information, but its text-heavy delivery may not be quite as digestible as the GUI's visualizations. That said, command-line options can be used to control the level of detail included in the DTC's output, which may help users weed

out information deemed overly technical and, ultimately, unnecessary (for an example of this, see Working with 40-track floppy disks).

Using and interpreting the graphical user interface (GUI):

CAPTURING DISK IMAGES

1. Launch the KryoFlux GUI, either by clicking the desktop icon, or by opening the DTC folder where the GUI installer was located and double-clicking on the file called kryoflux-ui.jar.

NOTE: Java is required in order to launch the GUI. Instructions for installing Java and other dependencies can be found in the Downloading the Software section.

2. At the beginning of each imaging session calibrate the floppy drive by selecting the correct drive from the *Drive* menu then selecting *Calibrate* from the same menu (see figure 9). You should only need to calibrate the drive once per imaging session and any time you switch between 3.5-inch and 5.25-inch disk drives.

NOTE: See the troubleshooting section if you experience difficulties in calibrating your drive when using the GUI.
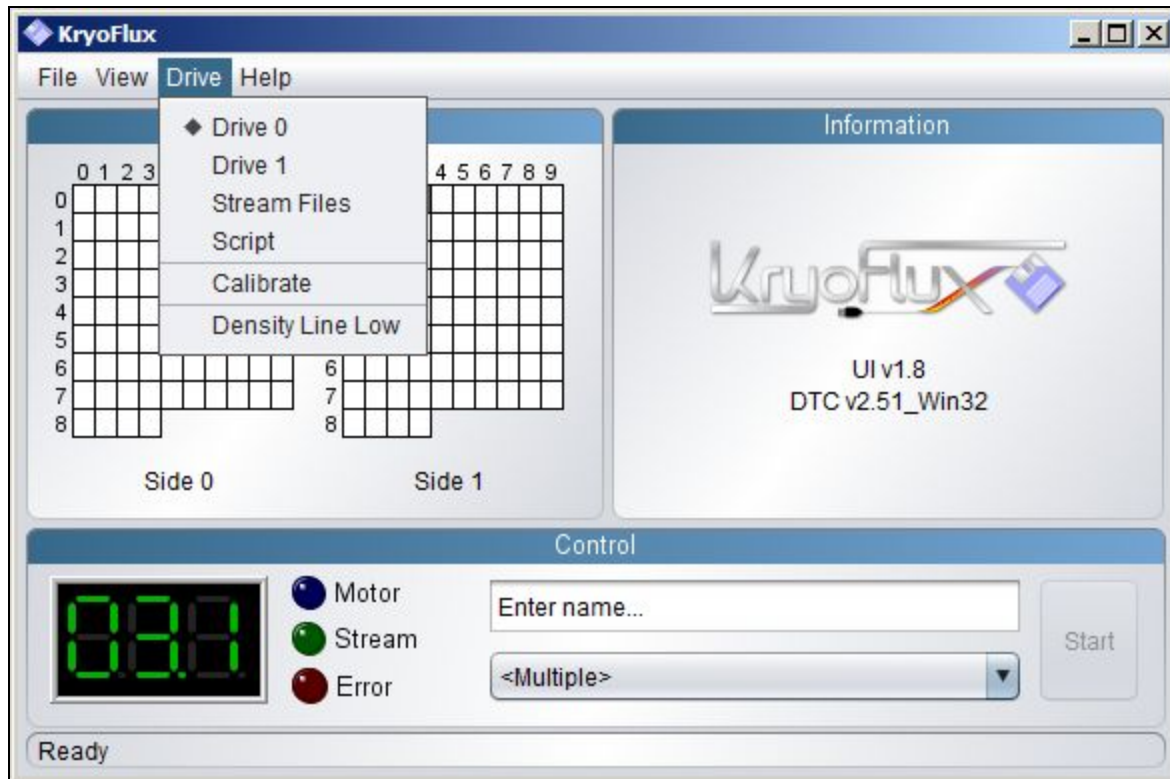
Figure 9: Select the correct drive from the Drive menu, then select Calibrate.

3. Configure the KryoFlux GUI to select the output directory for your newly-created disk images and log files. To do so, select *File → Settings* and click on the *Output* tab. Browse to the appropriate path to storage. Ensure that the *Logs* button is checked, and then click *OK* (see figure 10).
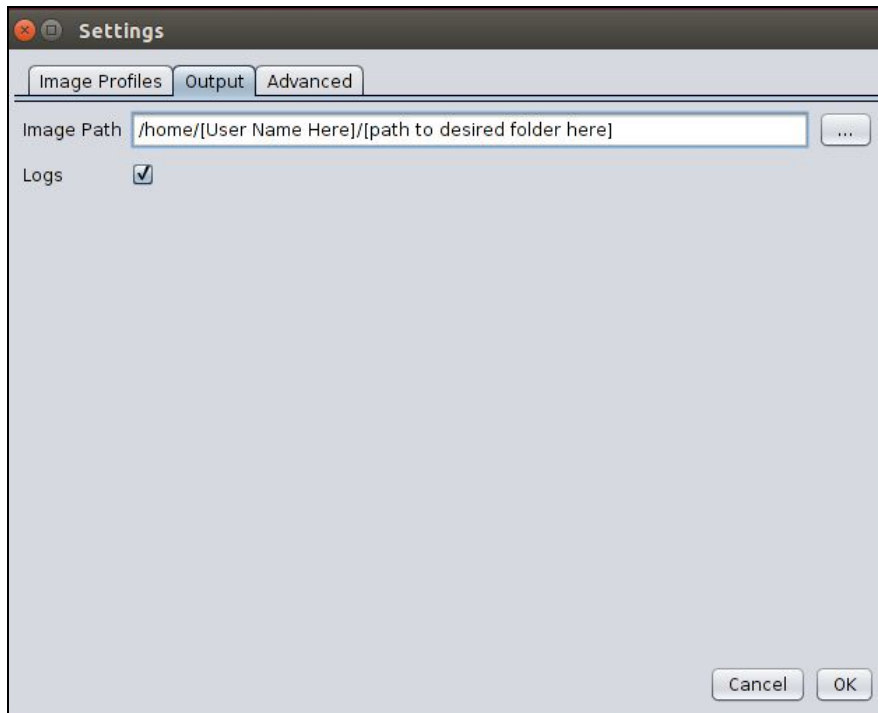
Figure 10: Enter the appropriate path to storage, check the Logs option and click OK.

4. For each disk, enter a unique identifier. Click on *Enter name…* and type in a unique ID associated with the disk. The text entered here will become the filename for any disk images and log files created. Do not include the extension of the file name.

5. Select the image format(s) for the disk image using the dropdown list below the filename field (see figure 12). Use the table below (figure 11) to select the necessary image formats. In order to choose multiple outputs, hold down the *Control* (*Ctrl*) key while making your selections. In most cases, selecting an image format to obtain a sector image requires that you know something about the media in hand.

NOTE: You may wish to capture preservation stream files (listed as *KryoFlux stream files, preservation*) in addition to a formatted disk image as part of your imaging workflow, since these stream files can be used later to create formatted disk images using *Deviceless Mode*.

Physical Format	System Format	KryoFlux Image Format
3.5" double density	Macintosh	Apple DOS 400K/800K sector image
3.5" double density	PC	MFM sector image
3.5" high density	Any	MFM sector image
5.25" double density	Kaypro	MFM sector image (40 track)
5.25" double density	PC	MFM sector image (40 track)
5.25" high density	PC	MFM sector image

Figure 11: Some of the most commonly used disk encoding formats supported by the KryoFlux. Details on how to handle 40 track images are covered in PART TWO.
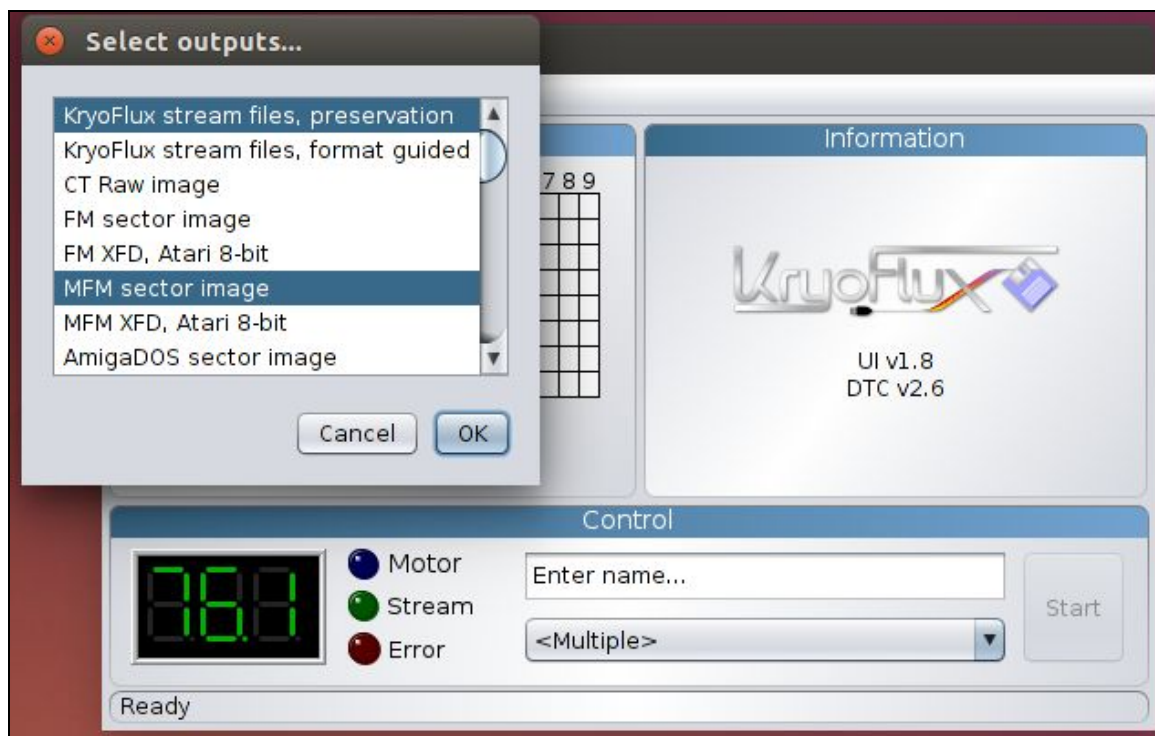

Figure 12: Select the image format(s) for the disk image using the dropdown list below the filename field.

6. After you have selected the appropriate image format, insert a disk and select *Start*. You should see the green *Stream* indicator flash on and off, and see the cells in the *Tracks* display on the left-hand side of the window fill with different colors (see figure 13).
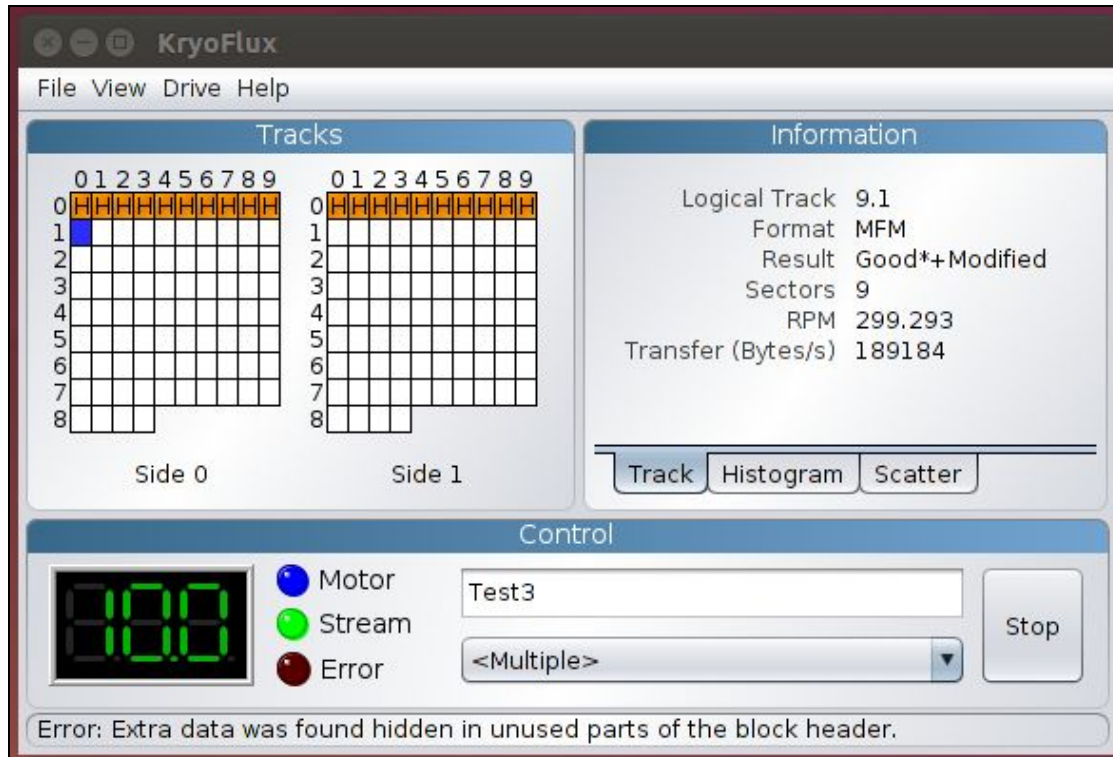

Figure 13: Once imaging has started, the green "Stream" indicator will flash on and off and the "Tracks" display on the left-hand side of the window will fill with blocks of color.

NOTE: The colors of the track cells mean the following:

Color of track cell	Meaning
Green	*Good*: The track was imaged successfully.
Orange	*Good+Modified*: The track was imaged successfully, but has one or more sectors that were modified after formatting or mastering. **NOTE:** The KryoFlux was designed to acquire unmodified copies of commercial software duplicated on commercial "mastering" machines. It is extremely likely that you will encounter many "good/modified" tracks on media received from donors. While this is

	a measure of authenticity designed by the developers of the KryoFlux, it is largely inapplicable to archival collections that focus on receiving papers and records of private donors or organizations.
Red	*Bad:* the track was not imaged successfully. **NOTE:** The KryoFlux can retry reads of a given track; this configuration option is available by selecting File → Settings and going to the Advanced tab.
Grey	*Unknown:* the KryoFlux software could not determine the status of this track. This may or may not mean a successful read. It could indicate that this track was unformatted or that the wrong format was selected at step 5. If you are creating only preservation stream files, all sectors will be grey.

7. Once the disk stops spinning and the green *Stream* indicator stops flashing, the imaging process has completed. The disk image(s) and log file for the disk you just imaged can be found in the directory you selected in step 3.
8. To image another disk, continue from step 4. If you switch drives (e.g. from imaging 3.5" disks to 5.25" disks) and have not calibrated the other drive, continue from step 3.

USING DEVICELESS MODE

Stream files created in KryoFlux can be used to create formatted images with the KryoFlux software.

If you have previously created stream files you can use this workflow to create images using the KryoFlux software without needing the hardware or disk itself.

1. At the beginning of each imaging session calibrate the drive by selecting *Stream Files* from the *Drive* menu. Unlike working with a physical drive, the stream file option does not require calibration.
2. Configure the KryoFlux GUI to select the output directory for your newly-created disk images and log files. To do so, select *File → Settings* and click on the *Output* tab. Browse to the appropriate path to the *Staging storage*. Ensure that the *Logs* button is checked, and then click *OK*.
3. For each disk, enter a unique identifier by clicking on *Enter name…* Type in the unique ID number. Do not include the extension of the file name.

4. Select the image format(s) for the disk image using the dropdown list below the filename field, select the necessary image formats from the table below. In order to choose multiple outputs, hold down the *Control* (*Ctrl*) key while making your selections.
5. Click *Start* and browse to the folder containing stream files.

The Floppy Disk Format Identifier Tool, created by Euan Cochrane, allows the user to create multiple image types over a directory of stream files from multiple disks. See Additional Tools and Resources for further information.

Using and interpreting DTC via the CLI:

KRYOFLUX COMMAND LINE SYNTAX

If you look at the command line examples listed further down this document, you will notice that all KryoFlux commands begin with `dtc`. This is because `dtc` is the name of the command that we execute whenever we run any task using the KryoFlux.

What comes after `dtc` depends on what task we want the KryoFlux to perform. KryoFlux's Disk Tool Console (DTC) provides a number of options that we can use—sometimes on their own, but more often in combination with other options. These options allow us to set the parameters of the command (for example, the file names we want to use or the encoding format in which we want to create our disk image). As with other command line tools, you may want to add the folder containing `dtc` to your operating system environment variables. Doing so will allow calling the application from any directory without specifying the absolute path to `dtc`. Steps to add system variables vary from system to system. See below for more information about how to add system variables.

Here's an example:

Command	Option	Parameter
`dtc`	`-f`	`kryofluxDiskImage_file`
Executes the DTC command	Serves as a flag to identify how the following parameter should be interpreted (in this case, it should be interpreted as a filename)	Provides our chosen filename (and, if necessary, its file path)

USEFUL COMMAND LINE OPTIONS

NOTE: In the following table, the KryoFlux user should replace the angle brackets (< >) and any text stored inside the angle brackets with the required information.

For example: -f<name> might become -f filename.img.
                -i<type> might become -i0

-f<name>	Used to set filename (and, if necessary, file path)
-i<type>	Used to determine image type. This relates to how data has been encoded on the floppy disk—which may or may not be known in advance of imaging. When used in a command, option –i is paired with a number representing a certain encoding format, e.g., STREAM = 0, MFM = 4, Apple DOS 400k/800k = 9. (See the KryoFlux manual for a full list of supported image types).
-m<id>	Set device mode. This option is used to generate additional disk images using existing STREAM files, rather than the original floppy disk.
-d<id>	Select drive, used if multiple drives are connected to KryoFlux (e.g., both a 3.5" and a 5.25" drive)
-l<mask>	Used to select the level of output generated during imaging. Using –l8 will restrict output to formatting information only, which can be used to verify data against a specified image type.
-t<try>	Used to specify the number of retries per track in the event that the KryoFlux encounters errors. The default number of retries is 5; increasing this number can sometimes help recover data from worn disks.
-p	Used to force creation of directories listed in file path
-dd<val>	Used to set drive density line (i.e., high density (HD) or double density (DD)). This is particularly useful when working with 5.25-inch drives. The disk may appear unformatted if the wrong density is used. This flag is less useful for 3.5-inch drives, which typically include a sensor to automatically detect the correct density.

COMMAND LINE EXAMPLES

Create stream files only:

```
dtc —fpath\to\new\streamFile -i0
```

Simultaneously create stream files plus formatted image files:

```
dtc —fpath\to\new\streamFile -i0 —fpath\to\new\formattedFile -i4
```

Create stream files and, in the process, validate against selected image types in order to determine disk formatting:

This command is helpful if you are not sure of the floppy disk's encoding format. Using option –i with the parameter 0 (-i0), creates stream files from your floppy disk. When we use option –i again, this time with parameters 4 (MFM) and 9 (Apple DOS 400k/800k) for example, the KryoFlux will validate the data on the disk against those encoding formats in order to determine which one (if either) is correct.

```
dtc —fpath\to\new\streamFile -i0 -i4 —i9
```

Limit output to formatting information only:

By default, output generated by the KryoFlux during imaging will include detailed technical information, not all of which will necessarily be relevant to you. This option, used with parameter 8 (-l8), can be added to the end of any command to limit output generated by the KryoFlux to encoding format information.

For example, the output generated by this command would only report whether the encoding format for data on the disk is MFM or Apple DOS 400k/800k:

```
dtc —fpath\to\new\streamFile -i0 -i4 —i9 —l8
```

Create formatted image files in deviceless mode (i.e., using stream files):

If you have already created stream files and now wish to create a disk image using one of KryoFlux's supported encoding formats (e.g., MFM), use the –m option to generate the new image file from data stored in the stream files, rather than on the original floppy disk. This is especially helpful if you don't initially know the floppy disk's encoding

format—you can validate and reimage using the stream files, rather than repeatedly running commands on a disk that is aging and potentially fragile.

```
dtc –fpath\to\existing\streamFile -i0 –fpath\to\new\formattedFile -i4
–m1
```

For people who are less familiar with the command line, here is an example of how the above command would look in practice, and a breakdown of its component parts:

```
dtc -fc:\Users\username\Desktop\Stream_Files\Track00.0.raw -i0
-fc:\Users\username\Desktop\Disk_1.img -i4 -m1
```

[dtc]: Command needed at the beginning to work in KryoFlux software
[-fc:\Users\username\Desktop\Stream_Files\Track00.0.raw]: File path (indicated by -f) to the first track in a folder of stream files ("Track00.0.raw")
[-i0]: The 0 in "i0" Indicates you are working with stream files
[-fc:\Users\username\Desktop\Disk_1.img]: File path to the image file. You are creating a new disk image, so you must name the new image file in the command line. Once you enter the command, the KryoFlux software will create the file "Disk_1.img." Be sure to include the extension .img or .E01.
[-i4]: indicates the file format of the disk image (see above).
[-m1] denotes that you are working in deviceless mode.

Force creation of directories in file path:

Use the –p option if some of the directories in your file path don't yet exist. This prevents you from having to manually create directories prior to running the command.

For example, this command would create the directories named UnitedStates and Georgia in the process of generating the stream file named Atlanta:

```
dtc –p –fUnitedStates\Georgia\Atlanta -i0
```

Sending DTC output to log file:

If you want to keep a copy of output generated during imaging for your records, this command will create a log file. However, note that this command sends output to the log file *instead* of the terminal window.

```
dtc –fpath\to\streamFile -i0 –fpath\to\formattedFile -i4 >
path\to\output.log
```

Using tee or Wintee to send DTC output to both DTC terminal and log file:

If you want to send output to both the terminal window *and* a log file, you will need to run an additional command alongside dtc.

On a Mac or Linux machine, use the command tee (tee is a native utility and does not need to be installed):

```
dtc –fpath\to\streamFile -i0 –fpath\to\formattedFile -i4 2>&1 | tee
path\to\output.log
```

Windows has no native utility for this purpose, but Wintee is a free utility that can be used for this purpose. Download Wintee prior to running this command:

```
dtc –fpath\to\streamFile -i0 –fpath\to\formattedFile -i4 2>&1 | wtee
path\to\output.log
```


Adding DTC to your System Variables:

Adding DTC to your System Variables (Windows)
1. Launch Control Panel-->System and Security-->System
2. Select *Advance system settings* on the left-hand panel
3. In the System Properties dialog, select *Environment Variables…*
4. In the Environment Variables dialog, select the Path line in the System Variables list and select *Edit…*
5. In the Edit environment variable dialog, select *New* and type the path to your DTC folder

Adding DTC to your System Variables (Mac)

The method for setting these variables changes dramatically from OS version to version. The following instructions should work in macOS 10.13, but your mileage may vary.

1. Launch terminal and ensure your working directory is your home directory.
2. Enter nano `.bash_profile` to create (or edit an existing .bash_profile file)
3. Enter `export PATH="[path to DTC]:$PATH"`
4. Save and close the .bash_profile file
5. Quit and relaunch Terminal.
6. Enter `echo $PATH` to confirm that DTC has been added as a variable.

Adding DTC to your System Variables (Ubuntu Linux)

Depending on the version of Linux, you might need to replace *.bash_profile* with *.profile* or *.bashrc*.

1. Launch terminal and ensure your working directory is your home directory.
2. Enter nano `.bash_profile` to create (or edit an existing .bash_profile file)
3. Enter `export PATH=$PATH:/path/to/dtc-dir`
4. Save and close the .bash_profile file
5. Enter `source ~/.bash_profile`

1. PART TWO: In-depth

The Archivist's Guide to KryoFlux is divided into two parts:
- Part one provides step-by-step instructions designed to get you set up and started. You may wish to start with part one if you already have a KryoFlux in hand and are ready to jump in. We've included links throughout part one to relevant sections in part two so you can dip in and out as needed.
- Part two provides a more in-depth introduction to the KryoFlux and floppy disks as a medium for data storage. You may wish to start with part two if you are interested in learning more about the ins and outs of how the KryoFlux works before diving in, or if you're weighing the benefits of purchasing a KryoFlux for your institution.

LOG FILES

The Disk Tool Console (DTC) application maintains a log of benchmarks as it runs over a floppy disk. If running the application on the command line (CLI), the user needs to specify a filename for the log to be saved as, otherwise it will print to stdout. By default, the graphical user interface (GUI) saves this file in the location specified during configuration. This section describes the information included in a log file and how it might be interpreted before discussing the merits of saving the log files as metadata or supporting documentation.

Log files in brief:

Somewhat confusingly, the logs output by the CLI and GUI are somewhat different in how each displays data, though the data conveyed is ultimately similar. A log file, regardless of its origin, contains the following information per track (and side, if applicable):

- tfer: the average transfer rate (bytes/second)
- rpm: revolutions per minute of the disk in the drive
- base: the base data band used in the track. This is calculated in two ways: from what is expected given the encoding scheme (MFM/FM/GCR) and what is detected on the disk surface by DTC. Data unit recorded in *µ*, though represented as *u* in the log file.
- band: the additional data bands used for recording information. Like the base, this is calculated both by detection and by what is expected by the encoding scheme directed by the user. Data unit recorded in *µ*, though represented as *u* in the log file. Per the official manual,[1] floppies encoded FM should expect 2 bands in addition to the base, and disks encoded either MFM or GCR should expect 3 bands in addition to the base.

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[1] http://www.kryoflux.com/download/kryoflux_manual.pdf

- encoding outcome: based on how encoding methods are specified by the user, the log will report whether DTC could successfully decode data, successfully decode data with warnings, or not successfully decode data. Warning codes are detailed on page 22 of the official KryoFlux manual (though, confusingly, warning codes are presented as lower-case letters in the manual, and upper-case letters in the log file).[2]

This data is presented in three line chunks, prefaced by a three-digit code specifying the track and side that the following data pertain to. In the following image, *05.0* refers to track 5, side 1. These lines will repeat if the user has specified that DTC should retry tracks more than once.

```
05.0     : frev: 83558, drift: 0.645 us, tfer: 393972 B/s, rpm: 300.905
05.0     : base: 1.003 us [99.690%], band: 1.999 us, 3.009 us, 3.982 us
05.0     : MFM: OK, trk: 005, sec: 18
```

The GUI log includes two extra features not present in the CLI log:
- The first line of a GUI-derived log file contains the corresponding command DTC ran as if it had run from the CLI
- A series of timestamps recorded in hexadecimal notation before each chunk of data listing the track and side information in a more human readable format.

```
00186209: motor=1
0018621d: side=0
00186232: track=5
00186278: stream=1
001864e7: stream=0
05.0     : frev: 77170, drift: 1.269 us, tfer: 360616 B/s, rpm: 300.923
05.0     : base: 1.004 us [99.248%], band: 1.978 us, 3.011 us, 4.035 us
05.0     : MFM: OK*, trk: 005, sec: 18, *H +4
```

Inferences from base and band information:

Looking more closely at the log file snippet below, there are a few inferences one may draw from the information presented.

```
05.0     : frev: 83558, drift: 0.645 us, tfer: 393972 B/s, rpm: 300.905
05.0     : base: 1.003 us [99.690%], band: 1.999 us, 3.009 us, 3.982 us
05.0     : MFM: OK, trk: 005, sec: 18
```

In this case, the user specified that DTC should treat the source floppy disk as one with MFM encoding. According to a discussion on the KryoFlux message board with two of the creators of

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[2] http://www.kryoflux.com/download/kryoflux_manual.pdf

the device,[3] MFM-encoded high density (HD) floppy disks should expect a base of 1 μ with bands at 2, 3, and 4 μs. In the example, DTC detected the base band at 1.003 μs and the additional bands at 1.999, 3.009, and 3.982 μs. This is as expected, and the data in the sector was successfully decoded to MFM.

Worth noting is that both the GUI and CLI allow the user to specify multiple types of sector image specifications at once, as well as the KryoFlux stream format. In the event that the user specifies a second or third type of sector image, the log should reflect the above information for each attempt. Further, because the KryoFlux stream function is encoding and format agnostic, this type of information is only available if the user specifies a sector image type.

What to do with log files:

How to treat log files generated by DTC in the long term will likely vary from institution to institution. It is useful in documenting the chain of custody of the disk and its contents--in fact an important document, as deriving a disk image is likely the first step an institution will take to stabilize its contents. Because it documents exactly what the DTC application found in each sector, it is also useful for reporting both the quality of the media and the actions taken by the archivist. Like stream files (described below), preserving the DTC log could aid future archivists when revisiting particularly troublesome floppies.

DISK IMAGE FORMATS

There are over 20 distinct types of disk images available using the DTC application, and trying to visually parse the list either in the GUI or from the CLI reference list in the official KryoFlux manual is daunting. This section will briefly cover the two broad categories of disk image types and the full range of options available to the user, before providing a longer discussion of the two more common formats one will likely encounter including how to configure the CLI and GUI to create them. The section will close with a discussion of KryoFlux preservation stream files, specifically addressing the format's positives and negatives.

Frequency modulation and group code recording:

Floppy disks can be divided into two categories based on the scheme computer systems use to encode data on the magnetic surface. The two families are Modified Frequency Modulation (MFM) (based on its predecessor Frequency Modulation (FM)), and Group Code Recording (GCR). The general user of the KryoFlux board does not need to know a huge amount of

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[3] http://forum.kryoflux.com/viewtopic.php?f=3&t=1044

information about either particular encoding method, but it is useful to keep in mind that MFM is a uniform method of encoding--meaning that MFM is generally better documented and closer to a standard--while GCR really refers to a number of related encoding methods primarily developed by Apple and Commodore Business Machines independently of one another. As implied by its name, MFM and FM encodes binary data through reversals in polarity and because of the translation from flux reversals and the data signified by those reversals, disks encoded using this method tend to be more uniform. GCR encoding methods rely on tables to translate flux reversals and those tables vary depending on the hardware, low-level driver software, and operating system.

As a rule of thumb, if you know what system a disk was used with and the approximate era, you can make an educated guess about whether it's MFM or GCR encoded. It is important to note, however, that a user may have purchased a disk meant for another system and reformatted it for use in their own machine--so it is important not to assume that a manufacturer's label claiming compatibility with one system means it is definitely formatted for use with that system.

Most commonly encountered options:

MFM/FM GENERIC SECTOR IMAGES

Generic MFM and FM encoded floppy disks are perhaps most common, particularly with disks used in the 1990s.[4] This is largely because IBM personal computers and IBM clones throughout the 1980s and 1990s encoded data using these methods, leading to wide use by users of MS-DOS and CP/M systems at work and in the home. Rising levels of interoperability between peripherals across these systems over time helped lead to increased market share.

If a set of disks was used with an MS-DOS machine from the mid-1980s through the early-2000s, it is almost certainly a MFM or FM-encoded disk. Disks using the generic FM and MFM profiles include single-sided/double-density floppies, double-sided/double-density floppies, and double-sided, high-density floppies in both 5.25" and 3.5" sizes.

APPLE DOS 400K/800K SECTOR IMAGES

Apple computers in the 1980s and early 1990s used variable speed floppy drives in order to increase the capacity over their PC counterparts. This allowed for disks to beat early PC disks in terms of raw storage, but made reading those disks on later Apple computers to be much more difficult. KryoFlux's use of the phrase *Apple DOS 400K/800K* is a bit of a misnomer in that this type of sector image may include Apple computers not running Apple DOS[5] (e.g., early

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[4] Pages 1-6 of this document have additional details on FM and MFM encoding.
http://info-coach.fr/atari/hardware/_fd-hard/AN-505.pdf accessed 05/03/2017
[5] https://groups.google.com/forum/#!topic/vintage-macs/CbD58EqcnUM accessed 12/5/2016

Macintosh computers). As a general rule, 400K refers to single sided/single-density floppy disks. These disks were most commonly created on Apple computers running System 0.7-System 7.1. 800K refers to the double-sided or double-density floppy disks created by machines running System 7.5 and later.[6] By the time Apple introduced the update to its HFS filesystem (HFS+), native support for the variable speed floppies had been deprecated. All of this is a long way of saying, if the user knows that a particular disk was written using an Apple computer made between 1985 and 1995 (generally), the image type to attempt would be the 400K/800K sector image.

Other disk image types available:

DISK IMAGE TYPES USING MFM AND FM ENCODING

Additional disk image types available when using KryoFlux include the following:
- MFM/FM XFD - used for disks from the Atari 8-bit line of computers. The FM XFD is compatible with the earlier models from that line, while the MFM XFD is compatible with the later models.
- AmigaDOS sector image - used for disks from the Amiga family of personal computers. Interestingly, the floppy disk controller in Amiga machines was capable of reading and writing both MFM and GCR encoded floppies. Given that MFM encoding was handled by the Amiga's CPU, it was even possible for users to implement custom encoding schemes.
- DEC RX01 and RX02 sector image - used for 8-inch disks specifically using the DEC-manufactured drives. While 8-inch drives made by other manufacturers were similar to later 3.5- and 5.25-inch successors, the DEC models worked specifically with PDP machines and were more idiosyncratic in nature.
- EMU sector image - used for disks that worked with the E-mu line of synthesizers. The synthesizers stored samples on floppy disks

DISK IMAGE TYPES USING GCR ENCODING

Additional disk image types available when using KryoFlux include the following:
- Apple DOS 3.x sector image, DSK DOS 3.3 Interleave - used for 5.25" floppy disks written to by Apple II family of computers in the early 1980s.
- CBM sector image, various subtypes - used for floppy disks used by the Commodore Business Machines family of computers in the 1980s. As indicated by the KryoFlux user guide, there are a number of subtypes of CBM disk; it appears that different manufacturers created variations of the format.

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[6] http://siber-sonic.com/mac/newmillfloppy.html accessed 12/5/2016

KRYOFLUX STREAM FILES

The KryoFlux stream file format is a proprietary, though publicly documented,[7] file format for each of the sectors found on a floppy disk. Compared to a disk image file, KryoFlux stream files comprising an entire disk are much larger--a set of stream files for a 1.44 megabyte (MB) floppy disk may be around 20-25 MB. While such a footprint is much smaller many other file types created in contemporary digital environments, it is considerably larger than the maximum capacity of a floppy disk. This, along with the proprietary nature of the stream file format, make it difficult to recommend a set of stream files as a preservation format.

Why work with stream files?

If stream files are so large and restrictive, why might a user want to work with them at all? First, stream files speak to one of KryoFlux's chief benefits--it divorces the understanding of the content fully from the stabilization of the content. It is entirely possible to create a set of stream files at one point in a workflow and not attempt to understand their contents until a later step.[8] The clear separation allows both for flexibility in workflow design, and the user to only access the potentially fragile disk surface once. This latter quality also speaks to a second benefit to working with stream files: the ability to tease out ambiguity. The discussion above about types of disk image formats available with the KryoFlux assumes the user has clear documentation of what type of computer during what era wrote to a disk. Unfortunately, that is not always the case. It is much more likely that a user might know the year (or range of years) that disks were used, but it is much less likely that a donor (or a donor's heirs) can recall exactly what type of computer they used at home or in the office 30 years prior to signing an agreement with an archives. In cases such as these, the user can create stream files and run those stream files against the DTC application, instead of running the KryoFlux DTC multiple times using trial and error against a potentially fragile source floppy disk. This is known as "deviceless mode." Deviceless mode can be used in either the command line or the GUI. For the command prompt command specific to deviceless mode, see the subsection titled "Create formatted image files in deviceless mode (i.e., using stream files)" on page 31. Euan Cochrane has created a tool[9] to take stream files and reduce trial and error by matching the stream files to one or more disk image types.

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[7] http://www.kryoflux.com/download/kryoflux_stream_protocol_rev1.1.pdf
[8] As discussed by Walker Sampson in the BitCurator Consortium's webinar on KryoFlux, https://bitcuratorconsortium.org/videos/advanced-topics-webinar-kryoflux
[9] http://digitalcontinuity.org/post/144268258748/floppy-disk-format-identifer-tool

If using the GUI, creating stream files comes with a third benefit. In addition to the color-coded blocks the GUI fills in as it moves throughout a disk's sectors, the GUI will also create a scatter plot and histogram of the flux transitions it finds for each sector. This is valuable when trying to determine if a particularly problematic disk is damaged or degraded, or if the user has not hit upon the correct image type yet. KryoFlux may report that a sector is unformatted, but unformatted sectors have a particular appearance in the scatterplot visualized by the GUI. If a sector is reported as unformatted, but one can make out a discernable pattern in the scatterplot, it is possible that data is in the sector.

Long term retention of stream files:

As mentioned above, KryoFlux stream files are created and stored in a proprietary format, and they are much larger in size than a disk image file. Whether or not to save stream files long term is a policy decision to be made institutionally. Duke University saves stream files in place of disk image files for disks in limited cases, but they do not save stream files long term as a general rule. Situations in which they have saved stream files include disks for which the GUI can reveal data in the sectors but staff have not been able to determine whether a particular image file was created successfully, disks from high profile donors that they have been unable to salvage, and disks from collections whose creators created or helped create new file formats. Finally, while Kryoflux can create disk images in a large number of sector image formats, these are only a portion of the floppy disk formats that were in use when floppy disks were a popular form of removable storage. Though perhaps uncommon, it is possible such formats are part of current collections and may currently be inaccessible. Storing a dump of such a disk in stream format will allow future archivists to revisit it.

UNDERSTANDING DRIVE 1/0

Each board comes with a floppy data cable which has two sections, each section has two connectors (one for each drive type, 3.5 and 5.25 inch). The section that is connected to the drive determines if that drive will appear as Drive 1 or Drive 0 in the GUI. The connectors closest to the KryoFlux board will usually appear as Drive 1 and the connectors furthest from the board appear as Drive 0. It's also important to note that you have to set the jumper on the board itself to support a dual drive setup.

When connecting the data cable to the drive you can only connect one drive to one section at a time. If you are connecting two drives to a kryoflux board, be sure that you use one connector from each section of the data cable. Make sure you have documented which drive is associated with which section. This will be important to know in order to calibrate the correct drive for use. The order of which drive is

associated with which drive number (1 or 0) does not affect the usage of the KryoFlux, but it must be documented in order to know which drive to calibrate.

WORKING WITH 40-TRACK FLOPPY DISKS

What are 40-track disks?

The magnetic medium inside a blank floppy disk is coated with magnetic oxide, with particles in no magnetic order. Formatting the disk aligns these particles into a pattern of tracks, which are concentric rings divided into sectors that represent locations where data is stored, with empty space between the rings. This also represents the structure that the stored data follows. Until the mid-1980s, floppy disks typically had 40 tracks each. These tracks were widely-spaced enough that drives would not accidentally overwrite data or write data to the wrong track by mistake. After the mid-1980s, changes in technology halved the physical distance needed between tracks, so more tracks (and data) could fit onto a disk. Floppy disks usually had 80 tracks after this point.

The KryoFlux's software images 80-track disks by default, and will not automatically image 40-track disks correctly. If you have a 40-track disk, you'll need to change the GUI's settings or image the disk using the command line interface in order to image it correctly.

Reading a 40-track disk with an 80-track drive can be difficult, since 80-track drives were generally not designed for this, but there are workarounds once you know you have a 40-track disk.

It can be difficult to identify a 40-track disk. One clue can be found by checking the disk's label, since some 40-track disks are labeled "48 tpi," or 48 tracks per inch. This refers to the density of the tracks on the floppy. If the label says "48 tpi," you can confirm that it is a 40-track disk via the command line and/or the GUI (see next section).

How to tell if you have one

40-track disks can often be identified in the GUI by the distinctive sector pattern they exhibit during imaging, wherein every other track is bad or unintelligible, as shown below. **If you notice this pattern while imaging is underway, it's important not to stop the process until it is finished, since stopping during imaging can damage the drive.**
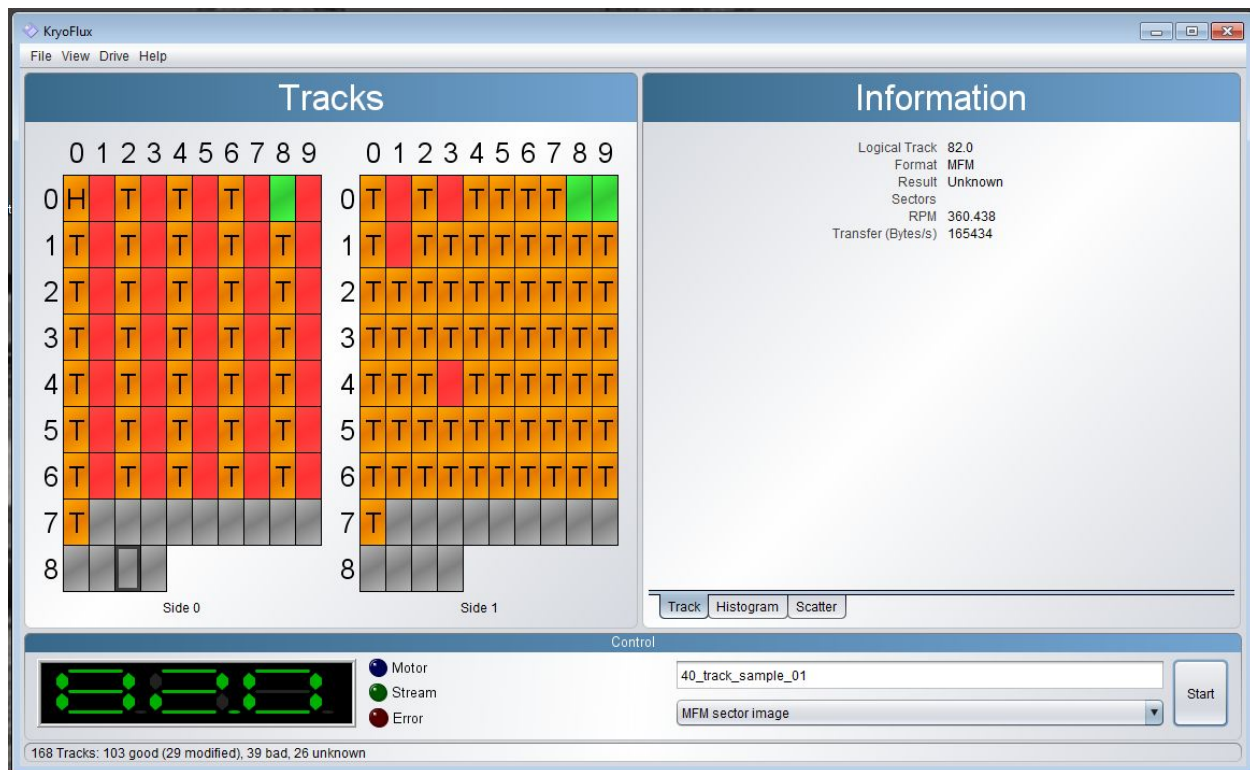
(Note that every other track on side 0 is bad; this is a sign that the floppy disk is likely a 40-track disk.)

The pattern occurs because the drive detects "crosstalk", or magnetic noise between tracks. The drive expects to see a new track, but does not find one because the disk has 40 wider tracks instead of 80 narrower tracks. The drive/KryoFlux may try to read tracks that shouldn't have readable data on a 40-track disk (the odd-numbered tracks), resulting in every other track appearing to be bad.

In order to confirm that this pattern indicates a 40-track disk, you will need to use the command line.

In the command line, navigate to the folder containing the DTC executable file, and enter

```
dtc -m1 -fpath\to\STREAM\file/* -i
-fpath\to\MFMimageFile/new_image_filename.img -i4 -l8
```

which will create an MFM image of the disk from stream files. (We chose to create an MFM image because we thought this was the most likely format for the disk we were imaging, and the output confirmed that we were right. If another format is more likely, the command you enter to

image the disk will be slightly different. See Using and interpreting DTC via the CLI for more information.)

Then look at the output:

After the first few lines, each line should look something like this:

```
02.0        :  MFM OK*, trk: 002[001], sec: 9, *HT      +5
```

Here, 02.0 is the track number, and MFM OK* means that the disk is MFM-formatted, so the MFM image will work. Trk: 002 means that the software expects to find track 2, and [001] means that it found track 001 instead.

The number after trk: and the number in the bracket will depend on the track. If there is a number in brackets, then the disk is a 40-track disk. This is because the brackets won't appear if the track number matches the number after trk. If they do not match, then the track number the program found will be listed in the brackets, and you'll know you have a 40-track disk.

In the output, H stands for header gap. If there's a header gap, that means that the track has been modified (in other words, the user wrote something to it) so it has data that we want. T represents the track warning, which is when the track number the software finds doesn't match the track number it should find. Each line of output also includes a number that represents the number of modified sectors on that track. In this case, there are 9 modified sectors.

An additional sign that you have a 40-track disk instead of an 80-track disk is that, after the first few tracks, every other track returns three lines: one that looks like the line shown above, but with MFM <error> instead of MFM OK*, one that says "Bad sector found," and one that says "Read operation failed." This is because there's no track for the software to read.

This table breaks down the sample line of output described above, and explains what each part means:

02.0 :	MFM	OK*,	trk: 002	[001],	sec: 9,	*HT	+5
Track number	Check for MFM formatting	Disk is MFM-formatted	Expecting to find track 2	Finds track 1 instead (difference signifies 40-track disk)	9 modified sectors	**H**eader gap (track has been modified), **T**rack warning	

Imaging 40-track disks

Command line

From the command line, navigate to DTC. Type in:

```
dtc -m1 -fpath\to\STREAM\files/* -i
-fpath\to\new\image\file/new_image_filename.img -k2 -i4 -l8
```

This tells the KryoFlux to create an MFM image of a 40-track disk from stream files. -k2 sets the track distance to 2, so DTC will image every other track (40 tracks instead of 80), and skip the parts of the disk that do not contain data. The screenshot below shows what this will look like in the command line.

GUI

To image 40-track disks, you will need to change some settings. You can create an imaging profile in the *Settings* tab to save these settings, and avoid having to change them manually every time you encounter a 40-track disk.

To do this:
1. Go to *File* > *Settings* > *Image Profiles* in the GUI.
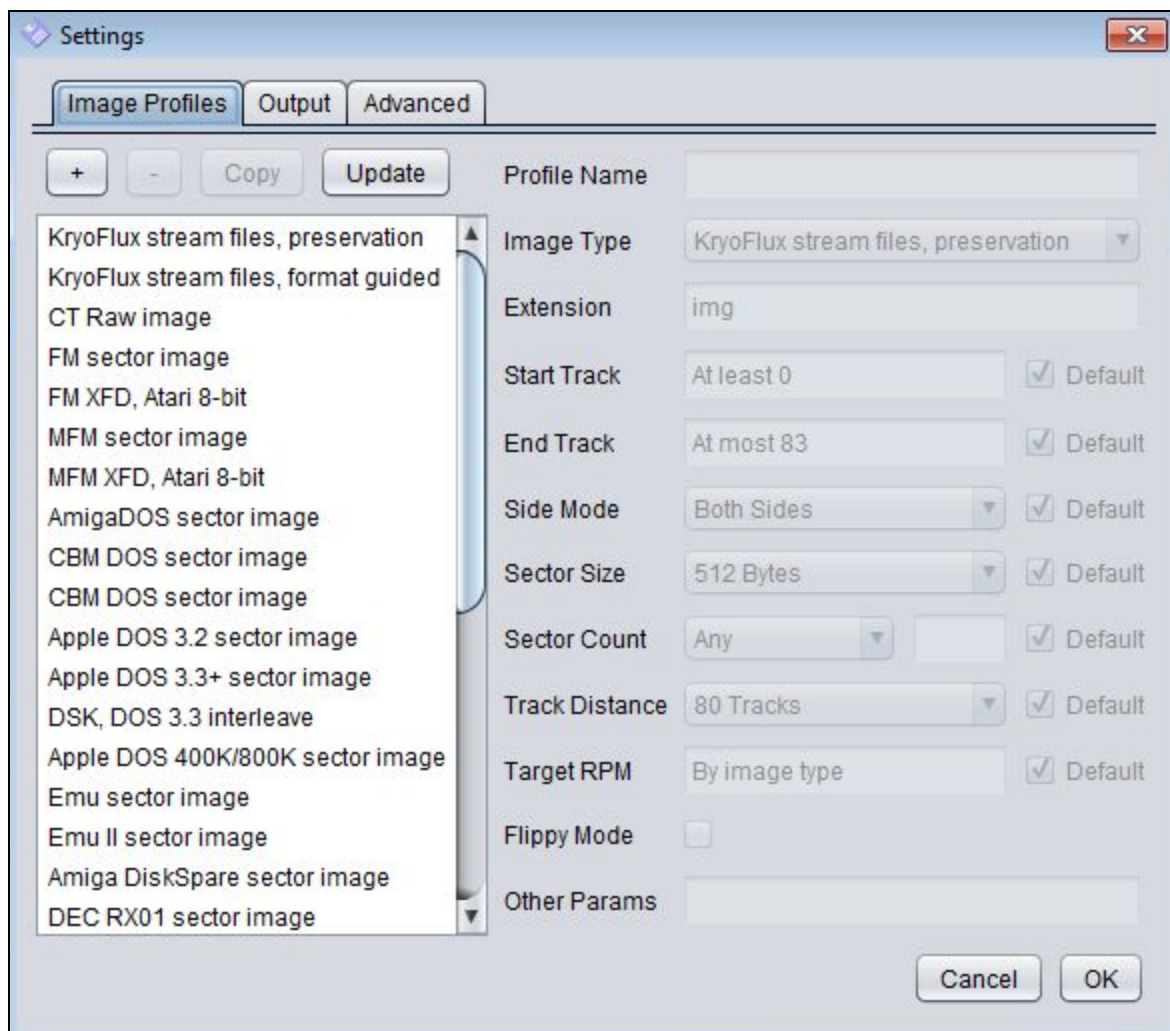
2. Make sure you're using the most up-to-date image profile for each format. To update the image profiles:
    a. Select each profile and click the minus sign to delete it.

b. Once you have deleted all the profiles, click *Update* to replace them with the most recent versions.

Once the profiles are up to date, it's time to create a 40-track version of the profile you need. If this version is lost, deleted, or changed, you can create another one using these instructions.

3. Select the format of the disk you're imaging (MFM sector, etc.) and click *Copy*. This will copy the image profile you want, so that you can change settings within the copy to accommodate a 40-track disk in that format, instead of having to create a profile from scratch.
4. In the *Settings* for the copy (on the right-hand side of the window), change the *Profile Name* to "[format] [40 tracks]" (e.g. "MFM sector [40 tracks]"), and unclick the *Default* box next to *Track Distance*. Change the *Track Distance* to *40 Tracks* in the pulldown menu. Click *OK*.
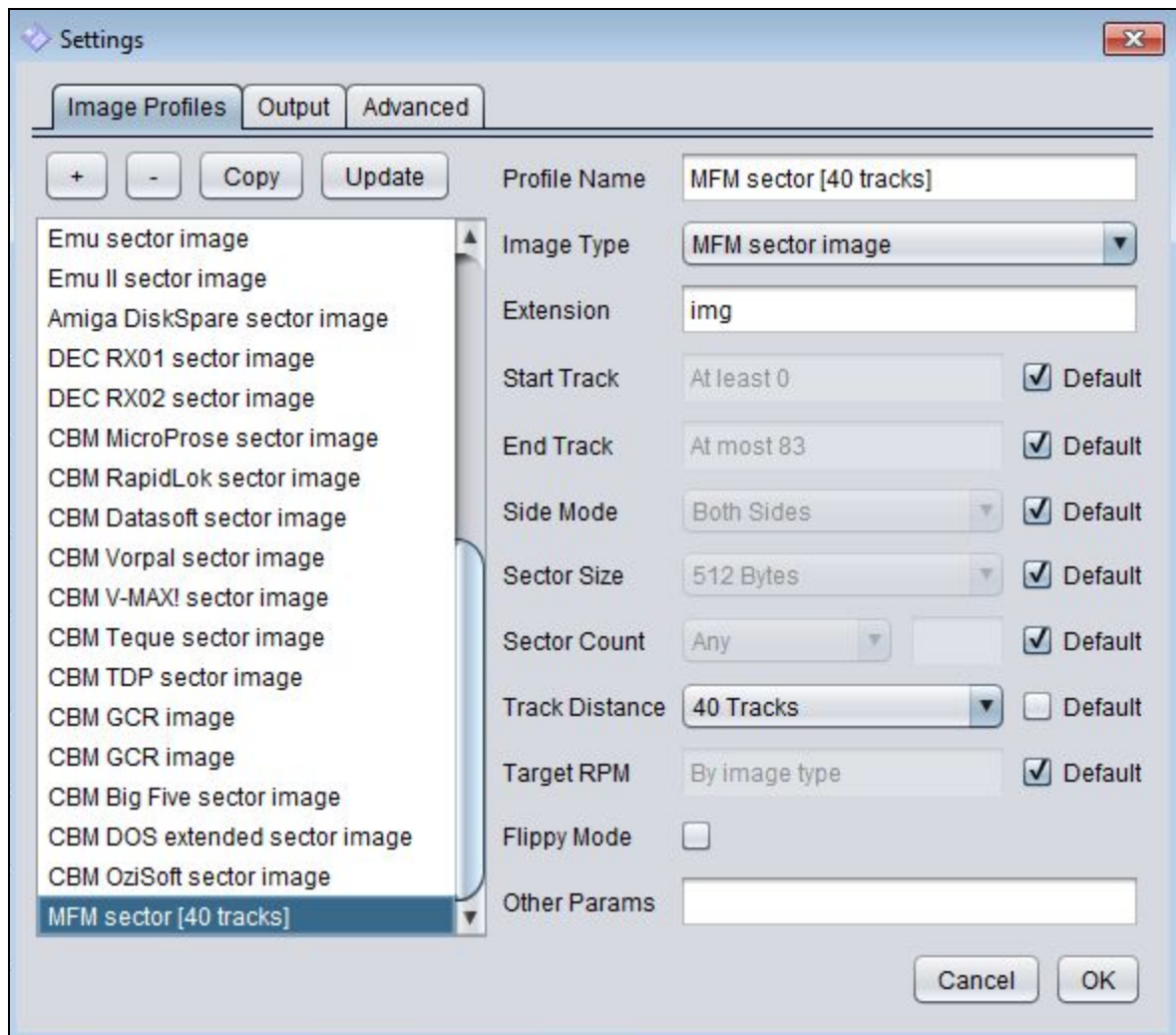
5. Every time you image a 40-track disk with the GUI, select the 40-track copy of the image profile you want to use in addition to preservation stream files. Then, create your disk image in the GUI as usual. The displayed result will look something like the screenshot below, with every other track unintelligible. This means the 40-track disk was imaged correctly.
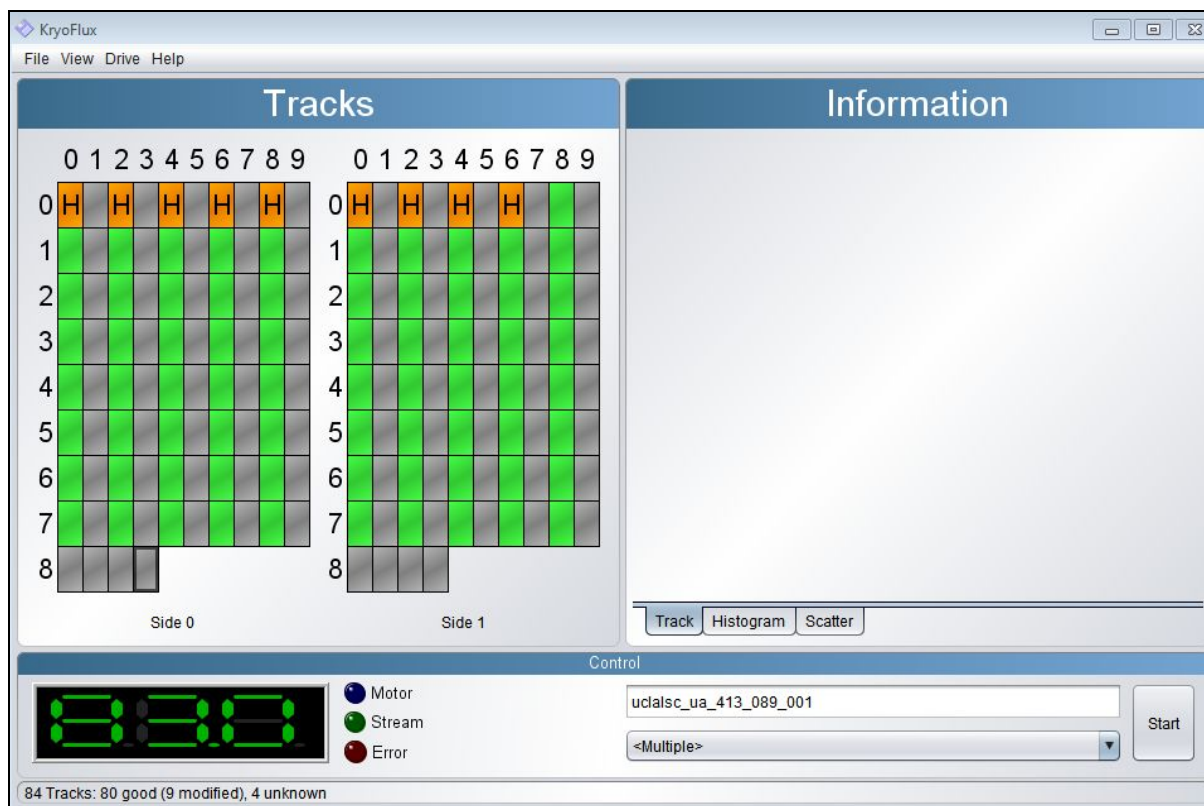
LESSONS LEARNED: KRYOFLUX TALES OF WOE

University of California Los Angeles

Patricia Ciccone, Victoria Maches, Shira Peltzman, Scott Reed

We ran into several issues while setting up the KryoFlux, both in terms of trouble with the physical setup process and problems with the KryoFlux after setup.

At first, it was unclear which connector on the floppy data cable we were supposed to use, though we figured out that the smaller connectors were for 3.5" floppy drives after looking up pictures of KryoFlux boards that had already been set up, and paying attention to which connectors had been used. The power supply adapter needed more strength to plug in than expected. We were concerned about breaking the adapter if we used too much force, especially since the individual cables in the adapter were not anchored well and moved out of alignment fairly often. After several unsuccessful attempts to plug the power supply into the adapter, we

decided our only option was to force it, which worked. Although we were concerned that we wouldn't be able to plug the drive power supply into the outlet without a converter (it had a European-style plug), the KryoFlux website suggested using the power cord half of a hard drive or laptop charger, which we happened to have on hand. (Pro tip: if you don't have one on hand, you can order one for around $4 online. See, for instance: https://www.computercablestore.com/10-ft-standard-laptop-power-cord-c7-wo-polarized).

We finished the physical set-up and were able to successfully download and install the DTC software without encountering any further problems, but we hit a major stumbling block when it came time to calibrate the drive. Calibration, which typically takes about 30 seconds to complete, repeatedly failed. Instead, after a wait of about 40 minutes, the DTC software returned an error. When we tried to calibrate the drive again after checking the drive cable and power supply connections, the same thing happened. When we tried again the next day, the red LED on the board went out, and the board never worked again. The same thing happened to our backup board when we tried to use it instead. At this point, we were still unsure of whether there was something wrong with the DTC software, or if we had damaged our boards.

We contacted KryoFlux, and they asked us to send the boards back so that they could assess the problem. We are still unsure of exactly what happened to our original boards, but after inspecting them, the KryoFlux folks provided us with their best guess as to what the problem might have been: Our computer's USB port may have provided too much power to the KryoFlux, which eventually caused the boards to fry. They assured us that future boards would have slower fuses in order to prevent this problem from happening again. Alternatively, we may have fried the boards by disconnecting them improperly, or the problem may have been some combination of these two issues (i.e. one board received too much power, and the other was improperly disconnected). However, the USB issue is our best guess at what happened, and we could not have prevented that. A later email from KryoFlux explained that our boards had blown fuses, and that these fuses could be replaced if this were to happen again.

To avoid frying the board by disconnecting it improperly, follow the instructions in Setting Up the KryoFlux and Disconnecting the KryoFlux.

NOTE: Christian Bartsch, Managing Director and Founder of KryoFlux Products and Services Ltd., provided some additional technical explanation related the experience that archivists and students from UCLA describe above:

Recent USB ports have become really powerful due to people charging their phones via the PC. Much of the "cheap" USB equipment simply does not have fuses, e.g. USB

hubs from China where the fuse (present on the board's layout) is simply bridged with wire.

So, KryoFlux has a fuse for various reasons. One is that drives, especially 5.25" and 8" drives, can generate significant (and unwanted) drainage and having a component (the KryoFlux) connected to something very powerful (the USB port) could cause damage. It might have happened that such drainage (which is a complex result of the different connections between the PC and the other outlet used for the PSU, plus the surface where the components are placed has triggered the fuse. [EDITOR'S NOTE: Always place the KryoFlux board on a non-conductive surface while it is in use. You may choose to use an anti-static mat or wristband, but typically this won't be necessary and there's debate about whether or not these types of anti-static devices will be helpful in a scenario like this one. NOTE: do not place the board on top of the anti-static bag in which the KryoFlux is shipped. The anti-static bags are conductive, and although the resistance is fairly high, it might cause data errors nonetheless.]

Such damage would only affect the fuse (as opposed to the board itself) which blows ("fries") for the reason of protecting 30+ year old technology.

The replacement fuse recommended is this one:

https://www.digikey.de/product-detail/en/bel-fuse-inc/0ZCJ0050FF2G/507-1802-1-ND/4156236?keywords=507-1802-1-nd&cur=EUR&lang=en

Having the fuse replaced by a trained technician will not void the warranty. Also, this replacement fuse, which is used for later KryoFlux boards, is self-resetting and will reset itself after a minute or two.

Princeton University

Elvia Arroyo-Ramirez, Kelly Bolding, Faith Charlton, Allison Hughes

Why won't the drive calibrate?
After setting up the KryoFlux and installing the driver in Windows per the software installation instructions (p. 8-10 of the official KryoFlux manual) with apparent success, we tried to calibrate it. The calibration worked fine in the command line (i.e., we typed "dtc -c2" and it gave us the message "CM: maxtrack=83") but when we attempted to calibrate in the GUI (which is what we really wanted to use, for the visualization tool and to make things easier for delegating bulk disk imaging work to student assistants) we got an error message: "Error: Could not communicate

with floppy drive." We tried disconnecting and restarting the computer but the problem persisted. We were super confused why it would be working in one place and not the other so we wrote to the KryoFlux support team, who advised us that we had probably selected the wrong drive in the GUI, and indeed, when we switched from Drive 1 to Drive 0 it worked with no problems.

It's unclear why switching from Drive 1 to Drive 0 solves this problem. We thought initially that perhaps our data cable connections were reversed, but feedback from the KryoFlux development team suggest this is incorrect. Whatever the reason, however, this solution worked for us and did not cause any damage to our KryoFlux board. In summary, if the KryoFlux won't calibrate using one drive, try the other.
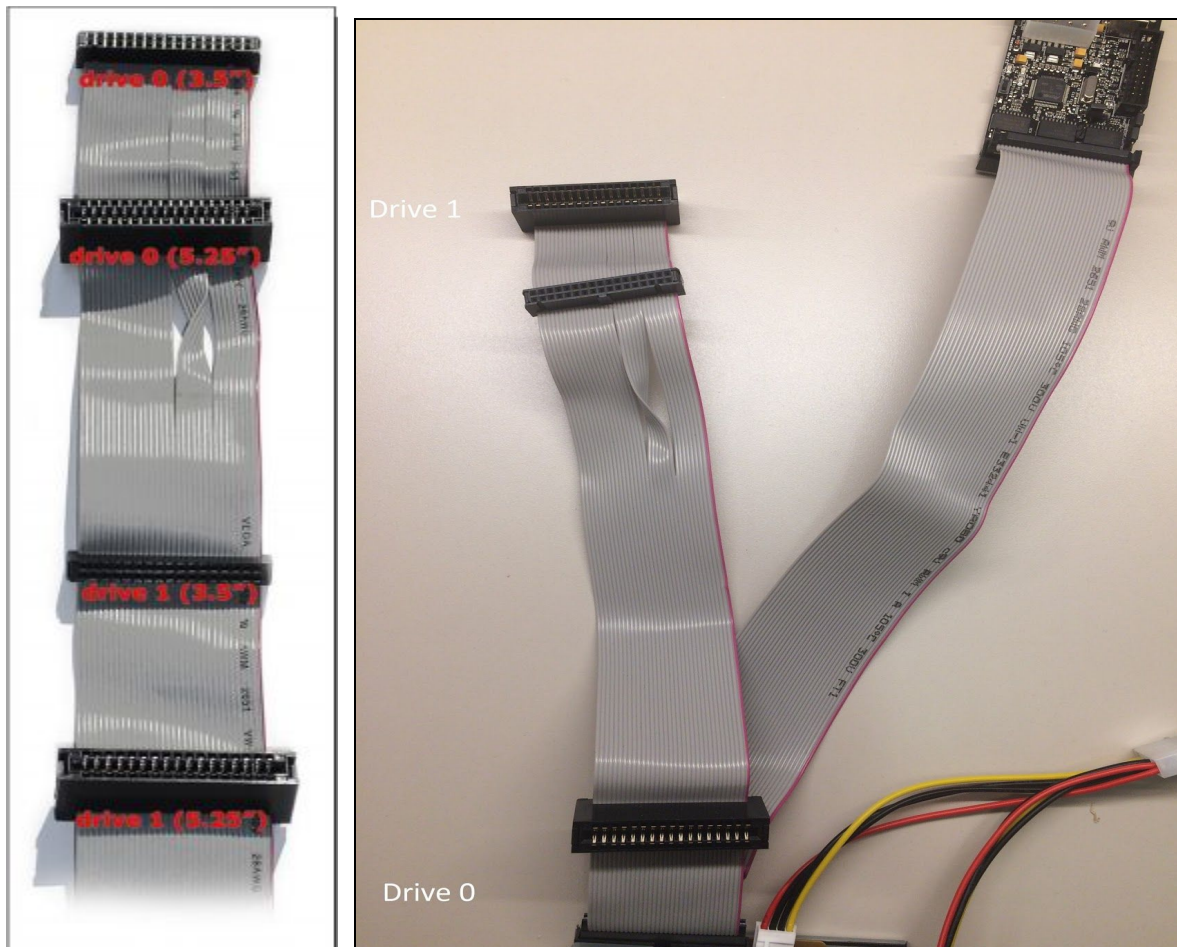
Why isn't the KryoFlux showing up when I plug it in?

It's showing up as a Bossa Port:
If the KryoFlux is coming up as a "Bossa" device, go to Device Manager -> Ports (COM & LPT). Right-click on the Bossa device listed and Uninstall, making sure that the "delete driver software" box is checked. Unplug the KryoFlux. Disconnect from the internet. Plug in the KryoFlux again and it should come up as "Unknown device". Install driver software from local files. Once it comes up as KryoFlux again you can turn the internet back on. Note that if you try to "update driver software," Windows will tell you you already have the best driver for the device installed and won't let you change to the KryoFlux driver.

It's not showing up at all:
If Windows is not recognizing anything when you plug in the KryoFlux, check whether it will recognize other USB devices. If the computer has stopped recognizing *any* USB devices, try Method 3 here: https://support.microsoft.com/en-us/kb/817900. This issue happened to us frequently when we were using the Kyroflux with a Dell laptop and regularly disconnecting and reconnecting it.

Why is the Settings window blank when I use the KryoFlux GUI?

At Princeton, even though Java was installed on the Ubuntu Linux workstation, archivists observed that the KryoFlux GUI did not call Java correctly when launching the GUI by clicking on "kryoflux-ui.jar." The GUI would appear to open correctly, but important functionality would be missing (such as a completely blank Settings window). We found a tip for bypassing this problem several paragraphs into the "README.linux file" that comes with the KryoFlux software download for Linux; these instructions indicate that the command "java -jar kryoflux_ui.jar" makes Java available when running the GUI. When we opened the GUI by running this command in the terminal, there was no more blank Settings window and the software was fully operational! To avoid having to run this command in the terminal every single time we use the GUI, we dropped the command into a very short bash script. As a workaround, archivists now use the script each time they launch the GUI. This script lives on the workstation's desktop and users click on it in order to start up the GUI in place of a desktop icon. The script we use is available on GitHub -- feel free to grab it; just be sure to edit the file path to match the installation location of your KryoFlux software package.

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*Troubleshooting

- **Why isn't my computer finding the KryoFlux?**

  If your KryoFlux isn't showing up as an unknown device or if your Windows instance seems to have forgotten the drivers in between KryoFlux sessions, it may be that it's being mistakenly recognized as Bossa Program Port. From the Device Manager window, search under Ports (COM & LPT). If you see Bossa Program Port listed, use the following steps to correct the problem (see also Princeton's Tale of KryoFlux Woe for an alternative solution, if this one fails):

NOTE: Administrative rights are required to add drivers to the computer. If you don't have admin access, contact your IT administrator for help.

1. Right-click on *Bossa Program Port*.
2. Select *Update driver software*.
3. Select *Browse my computer for driver software*.
4. Select *Let me pick from a list of device drivers on my computer*.

NOTE: If this is the first time you have done this, you may need to complete step 5. However, if you've done this once before, you may see the KryoFlux Disk System listed and can simply select it and proceed to step 6.

5. Browse to the KryoFlux drivers stored in the folder downloaded here.
6. Hit *Next*. You should see the following confirmation message: *Windows has successfully updated your driver software*.
7. Hit *Close*.

If you are still having trouble, try again from the beginning with the following steps:

The following instructions have been verified and written for Windows 10 Enterprise build 1703 x64. They are modified from those found on: https://forum.kryoflux.com/viewtopic.php?t=1038.

1. Connect the KryoFlux board.Verify the *Bossa device* is under *Unspecified* in the *Control Panel\All Control Panel Items\Devices and Printers*
2. Right click the Bossa device
3. Click on *propertie*s
4. Select the *hardware* tab
5. Click on *properties* at the bottom of the *hardwar*e tab
6. Click *change settings* at the bottom of the *General* tab
7. Select the *Driver* tab in the new dialog window
8. Click *Update Driver* in the Driver tab

9. Click *Browse my computer* for driver software
10. Check the box *Include subfolders* and then click *Browse*
11. Click the folder where the extracted KryoFlux files are
12. Click *OK*
13. Click *Next*
14. Install the drivers
15. Reboot (may not be necessary)
16. Open *Control Panel\All Control Panel Items\Devices and Printers*
17. Verify the device in *Unspecified* is listed as *KryoFlux DiskSystem*

If the drivers do not load, or it says you already have the latest driver:

1. Open *Control Panel\All Control Panel Items\Devices and Printers*
2. Right click the Bossa device
3. Click *Properties*
4. Select the *Hardware* tab
5. Click *Properties* at the bottom of the *Hardware* tab
6. Click *Change Settings* at the bottom of the *General* tab
7. Select the *Driver* tab in the new dialog window
8. Click *Roll Back Driver,* and accept all prompts to roll back the driver
9. Click *Update Driver* after the drivers have been rolled back and the *Roll Back Driver* option is not available
10. Check the box to *Always trust software*
11. Click *install* and close the dialog box
12. Verify the device in *Unspecified* has changed to *KryoFlux DiskSystem*

If the device reverts to *Bossa Program Port* after switching user accounts, even though it was not disconnected, follow these steps in **exactly the same order as they are listed**:

1. Delete the device
2. Unplug the power cord, unplug the usb cable
3. Plug the usb cable in the computer, plug the power cord back in.

If this doesn't work, it may be that your computer has stopped recognizing USB devices Altogether. Other workarounds not listed here may be necessary. See Princeton's Tale of KryoFlux Woe for one possible solution.

● **Why am I getting bcadmin permission errors when trying to run the KryoFlux using Linux BitCurator?**

If this is your first time installing the KryoFlux, you will also need to create a udev rule. The udev rule will prevent bcadmin permissions errors as well as erasing the need for the user to root. If this file is missing it is highly likely that the KryoFlux will not work properly.

If this is your first time installing the Kryoflux, you may need to also create a udev (Userspace Device) rule. This is often necessary to configure a Debian Linux (of which Ubuntu and BitCurator are flavors) environment, allowing access to the Kryoflux device for users in the *floppy* group. It is possible that BitCurator users will not need to to create a udev rule, as the default user (bcadmin) should already be part of the *floppy* group, however, some users report needing this udev rule on BitCurator systems as well as other Debian flavors of Linux.

See here for instructions to create a udev rule.

- **Why won't the drive calibrate when using the GUI?**

When using the GUI, the drive will not calibrate if you have selected the incorrect drive (for example, drive 1 instead of drive 0). Select the other drive and retry. For more information, see Understanding Drive 1/0 and Princeton's Tale of KryoFlux Woe.

- **Why is the Settings window blank when I use the KryoFlux GUI?**

At Princeton, even though Java was installed on the Ubuntu Linux workstation, archivists observed that the KryoFlux GUI did not call Java correctly when launching the GUI by clicking on "kryoflux-ui.jar." The GUI would appear to open correctly, but important functionality would be missing (such as a completely blank Settings window). For more information on how to address this, see Princeton's Tale of KryoFlux Woe.

- **DTC is reporting that it successfully created a sector image. Why can't I mount or export files from the image file?**

There is no single answer to this question, but here a few reasons why you might be unable to successfully mount or otherwise export logical files from a disk image.
- Many sectors were good or okay, but the sectors with important file system data were not due to bit rot and related media degradation.
- The file system is intact, but incompatible with the software you are to analyze the disk image. Since many forensic applications are designed to work with mainstream, contemporary systems, those that were obscure or mainstream but older often have compatibility issues.

- The disk image type selected was incorrect or some of the configuration options were incorrect. Certain disk image formats are similar enough to each other that selecting the wrong one will still result in a complete disk image. For example, a double-density 5.25" floppy when the options were configured for a single-density disk.

Glossary

Adapter or Converter:

Converter: Converters change the voltage from one level to another, usually from 220/240V to 110/120V.

Adapter: adapter is a device that adapts the attributes of one electrical device or system to those of an otherwise incompatible device or system. Some modify power or signal attributes, while others merely adapt the physical form of one electrical connector to another.

Command Line Interface (CLI):

The command line or Windows command line is a user interface that is navigated by typing commands when prompted, instead of using the mouse.

Degraded Data:

Decay of data in memory

Known as soft errors or bit rot, decay of data in memory can occur when the small electric charge of a dynamic random-access memory (DRAM) disperses. Memory can also be altered by other high-energy particles.

Decay of storage media

Data degradation can also be used to describe the phenomenon of storage media gradually decaying over the duration of many years. Common factors of storage media decay include sun exposure, dust, temperature, humidity, and other macro-environmental factors. For more information on ideal storage conditions for magnetic media, please see the Image Permanence Institute [Media Storage Quick Reference Guide](#).

Deviceless Mode:

Deviceless Mode means that the user can work on raw files without having to go through the Kryoflux hardware. The DTC will function like a virtual machine and will be able to read proprietary STREAM or DRAFT files. See [Using Deviceless Mode](#) for more information.

Disk Image:

A disk image is a perfect representation of the structure and contents of a storage device generated by the creation of a sector-by-sector copy of the source medium. It is system independent.

DRAFT files:

DRAFT FILES simply store the signals read from a disk. The interpretation of those signals is up to the application processing the file. All data is preserved at forensic quality in DRAFT, but it is a transient storage format, unlike a STREAM file format.

What's the difference between DRAFT vs STREAM?

The only difference between a STREAM file and a DRAFT file is that DRAFT is a one-file only image that is fit for transient storage while STREAM files comprised a group of files that represent signals from each tracks. Both are of forensic quality.

DTC:

The Kryoflux's Disk Tool Console, the command line application that sits underneath the Kryoflux's GUI. As the tool's underlying technology, DTC offers some added functionality and flexibility that might recommend it over the GUI in some instances. See GUI vs. DTC for more information.

Encoding Formats:

Encoding formats are information processing systems that convert raw data into a readable output. Encoding allows the circulation of data by giving instructional keys to a computer program to input, process and output data through a series of particular patterns. However, without the proper "reading keys" formatted content can be inaccessible. Kryoflux bypasses this problem by 1) providing a wide range of decoding tools/formats; and 2) preserving the magnetic flux of a disk rather than trying to output encoded data. See Disk Image Formats for more information.

Formatted Image:

A formatted image is an image file that is produced to be readable according to a certain encoding format. A formatted disk image means that the image can be visible through the standards associated with a specific processing system.

Legacy Floppy Disks:

A legacy device is a computing device that is outdated or no longer in production. Finding the right peripheral controller interfaces (PCI) for the device can be hard. The device might require manual configuration and jumper installation.

PSU:

Power Supply Unit (power cable).

Raw Magnetic Fluxes (floppy):

A floppy disk is a magnetic storage medium that can contain a certain number of reversals in magnetic flux, or the magnetic field of a given area. It includes the storage space itself, and a drive head that finds or makes polarity shifts on the disk, which are interpreted as computer code by the floppy disk drive. This means that the floppy drive would detect a change in the magnetic flux (interpreted as a 1) or no change (interpreted as a 0). Depending on the size of the disk, the fluxes are recorded at different speeds. These changes in magnetic flux represent the data stored on the floppy disk. Magnetic fluxes stored on a disk must be read exactly as written so that different drives detect the same changes, and can interpret the data in the same way.

Sectors:

A sector is a segment on a diskette or the disk where data is located. This division is a way to divide and organize the data on the disk or diskette so that it can be retrieved easily by read or write heads. Each sector is assigned a number and is combined with another number associated to the concentric rings that make up the tracks.

The smallest unit of storage is Sector 0 and it contains a FAT (file allocation table), which is a chart of numbers that correspond to cluster addresses on the drive.

STREAM format (proprietary):

The proprietary STREAM format reads the flux transition timing and index signal timing from the raw magnetic fluxes and encodes them in a specific standard. This standard recognizes the "stream file" as "one continuous stream of bytes." In other words, there's a start of the file, and an end to the file, but nothing else is defined (for floppy disks, however, temporal measures are part of the raw magnetic fluxes, and need to be taken into account when imaging). Stream files are reusable and allow you to create new disk images based on different encoding formats without re-reading the physical media, so your legacy media will not be compromised by being physically read too many times. See [KryoFlux Stream Files](#) for more information.

* Kryoflux stream files, preservation

The software validates the data read against the constraints normally used by generic MFM controllers/formats. If the decoder finds the data to be faulty, the software retries reading the track until the read is correct or there are no more retries allowed.

* Kryoflux stream files, format guided

The software records only tracks that would be normally used by the guide format. This is just for your records; think of it as logging the data the software processed for future reference. Using stream files this way does NOT set preservation parameters, but sampling is much faster.

What's the difference between DRAFT vs STREAM?

The only difference between a STREAM file and a DRAFT file is that DRAFT is a one-file only

image that is fit for transient storage while STREAM files comprised a group of files that represent signals from each tracks. Both are of forensic quality.

Tracks:

The magnetic media inside a blank floppy disk is coated with magnetic oxide, with particles in no magnetic order. Formatting the disk aligns these particles into a pattern of tracks, which are concentric rings where data is stored, with empty space between the rings. This also represents the structure the stored data follows. Until the mid-1980s, floppy disks had 40 tracks, but the space between tracks halved as technology changed, so 80 tracks could fit onto one disk.

Each track is further divided into sectors, which represent locations where data is stored.

Additional tools and resources

Tools:

Floppy Disk Format Identifier Tool
Created by Euan Cochrane, this tool lets users create multiple formatted disk images using a directory of stream files from multiple disks. Once the images have been created, the user can click 'Try Mounting' to mount every disk image created in the previous step. If the option "Delete unmountable' is chosen, then any disk image that failed to mount is automatically deleted. This leaves the user with a number of disk images that were successfully mounted. This is not a guarantee that the image format is the correct, only that the disk image can be mounted. The image files that are created keep the file name of stream file directory with an appended "-i" and a number. That number indicates the image type as listed on page 16 of the official KryoFlux User Manual.

Instructions and further description of the Floppy Disk Format Identifier Tool are available on the Digital Continuity Blog.

Books and articles:
- Durno, John. *Digital Archeology and/or Forensics: Working with Floppy Disks from the 1980s.* http://hdl.handle.net/1828/7611
- White, Ron and Timothy Edward Downs. *How Computers Work*. 10th Edition. How It Works Series. Indianapolis, IN: Que, 2014.

Web resources:

- Gough Lui's Project KryoFlux blog series: http://goughlui.com/2013/04/21/project-kryoflux-part-1-the-board-and-associated-hardware/ .
- KryoFlux Support Forum: https://forum.kryoflux.com/viewforum.php?f=3.
- 3D-Printed KryoFlux Enclosures**:** The files needed to print two slightly different models of KryoFlux enclosure are available at http://www.thingiverse.com/thing:64058 and http://www.thingiverse.com/thing:1025094. See Creating an Enclosure for more information.