The Law Enforcement and Forensic Examiner's Introduction to Linux

A Practitioner's Guide to Linux as a Computer Forensic Platform

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Legalities

Acknowledgments

As this guide grows in length and depth, so do the contributions I receive from others in the field that take time out of their own busy days to assist me in making sure that this document is at least accurate if not totally complete. I very much appreciate the proof reading and suggestions made by all. Every time I get comments back on a draft version of this guide, I learn something new.

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Also, I would like to specifically thank all of the Linux Kernel, various distribution, and software development teams for their hard work in providing us with an operating system and utilities that are robust and controllable. Too often we forget the amount of dedication and work that goes into what many end users expect to just “work”.

Foreword

This purpose of this document is to provide an introduction to the GNU/Linux (Linux) operating system as a forensic platform for computer crime investigators and forensic examiners.

This is the third major iteration of this paper. There is a balance to be met between maintaining the original introductory purpose of the work, and the constant requests from others coupled with my own desire to add more detailed content. Since the first release, this work has almost quadrupled in length. The content is meant to be "beginner" level, but as the computer forensic community evolves and the subject matter widens and becomes more mainstream, the definition of "beginner" level material starts to blur. As a result, I've made an effort to keep the material as basic as possible without omitting those subjects that I see as fundamental to the proper understanding of Linux and its potential as a computer forensic platform. A number of people have pointed out to me that with inclusion of some of the more complex exercises, this document should be given the more fitting "practitioner's guide" moniker rather than "beginner's guide".

We follow the philosophy that a hands-on approach is the best way to learn. GNU/Linux operating system utilities and specialized forensic tools available to investigators for forensic analysis are presented with practical exercises.

This is by no means meant to be the definitive "how-to" on forensic methods using Linux. Rather, it is a (somewhat extended) ***starting point*** for those who are interested in pursuing the self-education needed to become proficient in the use of Linux as an investigative tool. Not all of the commands offered here will work in all situations, but by describing the ***basic*** commands available to an investigator I hope to "start the ball rolling". I will present the commands, the reader needs to follow-up on the more advanced options and uses. Knowing *how* these commands work is every bit as important as knowing what to type at the prompt. If you are even an intermediate Linux user, then much of what is contained in these pages will be review. Still, I hope you find some of it useful.

Over the years I have repeatedly heard from colleagues that have tried Linux by installing it, and then proceeded to sit back and wonder "what next?" I have also entertained a number of requests and suggestions for a more expansive exploration of applications available to Linux for forensic analysis at the application level. You have a copy of this introduction. Now download the exercises and drive on.

As always, I am open to suggestions and critique. My contact information is on the front page. If you have ideas, questions, or comments, please don't hesitate to e-mail me. Any feedback is welcome.

This document is occasionally (infrequently, actually) updated. Check for newer versions (numbered on the front page) at the official site:

http://www.LinuxLEO.com

A word about the "GNU" in GNU/Linux

When we talk about the "Linux" operating system, we are actually talking about the GNU/Linux operating system (OS). Linux itself is *not* an OS. It is just a kernel. The OS is actually a combination of the Linux kernel and the GNU utilities that allow us (more specifically our hardware) to interact with the kernel. Which is why the proper name for the OS is "GNU/Linux". We (incorrectly) call it "Linux" for convenience.

Why Learn Linux?

One of the questions I hear most often is: "why should I use Linux when I already have [*insert Windows GUI forensic tool here*]?" There are many reasons why Linux is quickly gaining ground as a forensic platform. I'm hoping this document will illustrate some of those attributes.

- Control – not just over your forensic software, but the whole OS and attached hardware.
- Flexibility – boot from a CD (to a complete OS), file system support, platform support, etc.
- Power – A Linux distribution *is* (or can be) a forensic tool.

Another point to be made is that simply knowing *how* Linux works is becoming more and more important. While many of the Windows based forensic packages in use today are fully capable of examining Linux systems, the same cannot be said for the examiners.

As Linux becomes more and more popular, both in the commercial world and with desktop users, the chance that an examiner will encounter a Linux system in a case becomes more likely (especially in network investigations). Even if you elect to utilize a Windows forensic tool to conduct your analysis, you *must* at least be familiar with the OS you are examining. If you do not know what is normal, then how do you know what does not belong? This is true on so many levels, from the actual contents of various directories to strange entries in configuration files, all the way down to how files are stored.

While this document is more about Linux as a forensic tool rather than analysis of Linux, you can still learn a lot about how the OS works by actually *using* it.

Conventions used in this document

When illustrating a command and it's output, you will see something like the following:

```
root@rock:~# command
output...
```

This is essentially a command line (terminal) session where...

```
root@rock:~#
```

...is the command prompt, followed by the command (typed by the user) and then the command's output. The command will be shown in bold text to further differentiate it from command output.

In Linux, the command prompt can take different forms, depending on the environment settings (the default differs among distributions). In the example above, the format is

```
user@hostname directory #
```

meaning that we are the user "*root*" working on the computer named "*rock*" currently in the directory *root* (the root user's home directory – in this case, the "home directory" is symbolized by the shorthand representation of the tilde "~"). Note that for a "*root*" login the command prompt's trailing character is `#`. If we log in as a regular user, the default prompt character changes to a `$`, as in the following example:

```
bgrundy@rock:~$
```

This is an important difference. The "*root*" user is the system "superuser". We will cover the differences between user logins later in this document.

I. Installation

First and foremost, *know your hardware*. If your Linux machine is to be a dual boot system with Windows, then use the Windows Device Manager to record all your installed hardware and the settings used by Windows. If you are setting up a standalone Linux system, then gather as much documentation about your system as you can. **This has become much less important with the evolution of the Linux install routines**. Hardware compatibility and detection have been *greatly* improved over the past couple of years. Some of the recent versions of distributions, like Ubuntu Linux, have extraordinary hardware detection.

- Hard drive – knowing the size and geometry is helpful when planning your partitioning.
- SCSI adapters and devices (note the adapter chipset). SCSI is very well supported under Linux.
- Sound card (note the chipset).
- Video Card (important to know your chipset and memory, etc.).
- Monitor timings.
- Horizontal and vertical refresh rates.
- Network card (chipset).
- Network Parameters:
- IP (if not DHCP)
- Netmask
- Broadcast address
- DNS servers
  - Default gateway
- USB controller support is standard in current distributions.
- IEEE1394 (Firewire) controller support is also standard in current distributions.

In the vast majority of cases, most of this information will not be needed. But it's always handy to know your hardware if you must trouble shoot.

Most distributions have a plethora of documentation, including online help and documents in down loadable form. Do a Web search and you are likely to find a number of answers to any question you might have about hardware compatibility issues in Linux.

Distributions

Linux comes in a number of different "flavors". These are most often referred to as "distributions" ("distro"). Default kernel configuration, tools that are included (system management and configuration, etc.) and the package format (the upgrade path) most commonly differentiate the various Linux distros.

It is common to hear users complain that device *X* works under Suse Linux, but not on Red Hat, etc. Or that device *Y* did not work under RedHat version 9, but a change to CentOS "fixed it". Most often, the difference is in the version of the Linux *kernel* being used and therefore the updated drivers, or the patches applied by the distribution vendor, not the version of the distribution (or the distribution itself).

Here's an overview of just a few of the Linux distros that are available. Selecting one is a matter of preference. Many of these distros now provide a "live CD" that allows a user to boot a CD into a fully functional operating environment. Try them out and see what pleases you.

Red Hat / Fedora

One of the most popular Linux distributions. Red Hat works with companies like Dell, IBM and Intel to assist businesses in the adoption of Linux for enterprise use. Use of RPM and Kickstart began the first "real" user upgrade paths for Linux. Red Hat has elected to move into an enterprise oriented business model. It is still a viable option for the desktop through the "Fedora Project" (http://fedoraproject.org/) . Fedora is an excellent choice for beginners because of the huge install base and the proliferation of online support. The install routine is well polished and hardware support is well documented. Another Red Hat based distribution is *CentOS.*

Debian

Not really for beginners. The installation routine is not as polished as some other distributions. Debian has always been a hacker favorite. It is also one of the most "non-commercial" Linux distributions, and true to the spirit of GNU/GPL. (http://www.debian.org/).

SuSE

Now owned by Novell, SuSE is originally German in origin. It is by far the largest software inclusive distribution. (http://www.novell.com/linux/). There is an "open" support network and download directory at http://www.opensuse.org. A Live CD is also available.

Mandriva Linux

Formerly known as "Mandrake". Mandriva is a favorite of many beginners and desktop users. It is heavy on GUI configuration tools, allowing for easy migration to a Linux desktop environment. (http://wwwnew.mandriva.com/).

Gentoo Linux

Source-centric distribution that is optimized during install – one of my personal favorites. Once through the complex installation routine, upgrading the system and adding software is made extremely easy through Gentoo’s “Portage” system. *Not* for beginners, though. You are left to configure the system entirely on your own. If you have endless patience and *a lot* of time, it can be a fantastic learning experience. (http://www.gentoo.org/).

Ubuntu Linux

A relative newcomer, Ubuntu Linux is based on Debian and although I've not used it myself, it has a reputation for fantastic hardware detection and ease of use and installation. (http://www.ubuntulinux.org). I've heard that this is a great choice for beginners.

Slackware

The original commercial distribution. Slackware has been around for years. Installation is now almost as easy as all the others. Good standard Linux. Not over-encumbered by GUI config tools. Slackware aims to produce the most “UNIX-like” Linux distro available. One of my personal favorites, and in my humble opinion, currently one of the best choices for a forensic platform. (http://www.slackware.com/). This guide is tailored for use with a Slackware Linux installation.

Lot's of information on more distributions than you care to read about is available at http://www.distrowatch.com.

My suggestion for the absolute beginner looking to experience an overall “desktop” OS would be either the newest version of Fedora Core or Ubuntu. If you really want to “dive in” and bury yourself, go for Gentoo, Slackware or Debian. If you choose one of these latter distributions, be prepared to read…a lot.

If you are unsure where to start, will be using this guide as your primary reference, and are interested mainly in forensic applications of Linux, then I would suggest Slackware. More on why a little later.

One thing to keep in mind: As I mentioned earlier, if you are going to use Linux in a forensic capacity, then try not to rely on GUI tools too much. Almost all settings and configurations in Linux are maintained in text files (usually in either your home directory, or in */etc*). By learning to edit the files yourself, you avoid problems when either the X window system is not available, or when the specific GUI tool you rely on is not on a system you might come across. In addition, knowledge of the text configuration files will give you insight into what is “normal”, and what might have been changed when you examine a subject system. Learning to interpret Linux configuration files is all part of the "forensic experience".

SLACKWARE and Using this Guide

Because of differences between distributions, the Linux flavor of your choice can cause different results in commands' output and different behavior overall. Additionally, some sections of this document describing configuration files or startup scripts, for example, might appear vastly different depending on the distro you select.

If you are selecting a Linux distribution for the sole purpose of learning through following along with this document, then I would suggest ***Slackware***. Slackware is stable and does not attempt to enrich the user's experience with cutting edge file system hacks or automatic configurations that might hamper forensic work. Detailed sections of this guide on the inner workings of Linux will be written toward a basic Slackware installation (currently in version 12.1).

Previous versions of this document attempted to be far more distro independent. The examples and discussions of configuration files were focused on the more popular distribution formats. In the intervening years, there has been a veritable explosion of different flavors of Linux. This guide has been linked on a number of websites, and has been used in a variety of training forums. As a result of these changes, I have found myself receiving numerous e-mails asking questions like "The output I get does not match what's in your guide. I'm using 'Fuzzy Kitten Linux 2.0' with kernel version 2.6.16-fk-14-5.2...What could be wrong?" My reply has become standard to such queries: "I'm not familiar with that version of Linux, and I'm not sure what changes have been made to that kernel". Providing answers to questions on the exercises that follow requires that I know a little about the environment being used. To that end, I've decided to point people towards a standard, stable version of Linux that includes few surprises.

By default, Slackware's current installation routine leaves initial disk partitioning up to the user. There are no default schemes that result in surprising "volume groups" or other complex disk management techniques. The resulting file system table (also known as "*fstab*") is standard and does not require editing to provide for a forensically sound environment, unlike some other popular distributions.

The most recent version of Slackware (12.x) now uses the 2.6 series kernel by default. In many circumstances, your hardware will require you that use a 2.6 kernel (certain SATA controllers, etc.). In recognition of this, the current version of this document now assumes that the user has installed a 2.6 kernel version of Linux. This brings the LinuxLEO Practitioner's Guide in line with the majority of forensic practitioners currently using Linux, including myself. Previous versions of this document suggested a 2.4 (kernel version) install.

Slackware Linux is stable, consistent, and simple. As always, Linux is Linux. Any distribution can be changed to function like any other (in theory). However, my philosophy has always been to start with an optimal system, rather than attempt to “roll back” a system heavily modified and optimized for the desktop rather than a forensic workstation.

If you are comfortable with another distribution, then by all means, continue to use and learn it. Just be aware that there may be customizations and modifications made to the standard kernel and file system setups that might not be ideal for forensic use. These can always be remedied, but I prefer to start as close to optimal as possible.

Installation Methods

- Download the needed ISO (CD image) files, burn them to a CD and boot the media. This is the most common method of installing Linux. Most distros can be downloaded for free via http, ftp, or torrent. Slackware is available at http://www.slackware.com. Have a look at http://linuxlookup.com/linux_iso or http://distrowatch.com/ for information on downloading and installing other Linux flavors.

- Use a bootable Linux distribution (covered later). For example, the SMART or Helix Linux bootable CDs can easily be used as experimental platforms. See http://www.asrdata2.com or http://www.e-fense.com/helix for more information.

During a standard installation, much of the work is done for you, and relatively safe defaults are provided. As mentioned earlier, hardware detection has gone through some great improvements in recent years. I strongly believe that many (if not most) Linux distros are far easier and faster to install than other “mainstream” operating systems. Typical Linux installation is well documented online (check the “how-tos” at the Linux Documentation Project: http://www.tldp.org/). There are numerous books available on the subject, and most of these are supplied with a Linux distribution ready for install.

Familiarize yourself with Linux disk and partition naming conventions (covered in Chapter II of this document) and you should be ready to start.

Slackware Installation Notes

As previously mentioned, it is suggested that you start with Slackware if this is your first foray into Linux and forensics AND you primary interest is forensics. If you do decide to give Slackware a shot, here are some simple guidelines. The documentation provided on Slackware's site is complete and easy to follow. Read there first...

Decide on standalone Linux or dual boot.

- Install Windows first in a dual boot system. If you have Vista, be careful there are issues you should be aware of. Research dual booting with Vista before proceeding.
- Determine how you want the Linux system to be partitioned.
- Do NOT create any extra partitions with Windows **fdisk**. Just leave the space unallocated. Slackware will require you to utilize Linux **fdisk** or another partitioning tool at the start of the install process.

READ through the installation documentation *before* you start the process. Don't be in a hurry. If you want to learn Linux, you have to be willing to read. For Slackware, have a look through the installation chapters of the "Slackbook" located at *http://www.slackbook.org* . For a basic (but detailed) understanding of how Linux works and how to use it, the Slackbook should be your first stop.

1) Boot the Linux media. Slackware requires only the first two installation disks (or the single DVD).

- Read each screen carefully.
- Accepting most defaults works.
- Your hardware will be detected and configured under most (if not all) circumstances. On line support is extensive if you have problems.
- Keep in mind that if a piece of hardware causes problems during an install, or is not detected during installation, this does not mean that it will not work. Install the operating system and spend some time troubleshooting. When learning Linux, Google is very often your best friend (try *http://www.google.com/linux*).
- The Slackware install CD for the current version (12.1) will boot by default using a kernel called "hugesmp.s". It includes support for most hardware by default and supports multiple CPUs. If it does not work, then try the single CPU i486 kernel "huge.s". Hit the "F2" key at the initial "boot:" prompt for more info.
- Once the system is booted, you are presented with the "slackware login:" prompt. READ THE ENTIRE SCREEN as instructed. Login as root, and continue with your install routine.
- The main install routine for Slackware is started with the command **setup**. You will need to ensure that you have your disk properly partitioned **before** you enter the setup program.
- Take the time to read each screen completely as it comes up.

2) Partition and format for Linux
   - At a minimum you will need two partitions. This step is normally part of the installation process, or is covered in the distribution's documentation.
     - *Root* (/) as type "Linux Native".
     - *Swap* as type "Linux Swap" (use 2x your system memory as a starting point for swap size).

   - You will hear a lot about using multiple partitions for different directories. Don't let that confuse you. There are arguments both for and against using multiple partitions for a Linux file system. If you are just starting out, use one large root (/) partition, and one swap partition as described above.
   - You will partition your Slackware Linux system using **fdisk** or **cfdisk**. The Slackbook has a detailed section on using **fdisk** to accomplish this. (http://www.slackbook.org/html/book.html#INSTALLATION-PARTITIONING). In fact, I would read the entire installation section of the Slackbook. It will make the process *much* easier for you.
   - When asked to format the root partition, I would suggest selecting the e*xt3* file system (Now default in Slackware 12.1).
3) Package installation (system)
   - When asked which packages to select for installation, it is usually safe for a beginner to select "everything" or "full". This allows you to try all the packages, along with multiple X Window desktop environments. This can take as much as 5 to 6GB on some of the newer distributions (5GB on Slackware), however it includes *all* the software you are likely to need for a long time (including many "office" type applications, Internet, e-mail, etc.). This is not really optimal for a forensic workstation, but for a learning box it will give you the most exposure to available software for experimentation.
4) Installation Configuration
   - Sound
     - Usually automatic. If not, search the Web. The answer is out there. If it does not work "out of the box" (as it should with most hardware in Slackware), then try the following.
     - There are many current distributions using the "Advanced Linux Sound Architecture" (ALSA), including Slackware. Configuring sound on Linux using ALSA can be quite easy. Once booted into your new system, try running the command **alsaconf** to allow the system to attempt automatic configuration. If that appears to work (no obvious error messages), run **alsamixer** to adjust speaker volume. These programs are run from a command prompt. The **alsaconf** program is run as the root user, while **alsamixer** can be run as a regular user.

- Xorg (X Window system)
    - Know your hardware (video card, etc.).
    - If you choose to configure X during the installation routine, **do not** click "yes" if the installation routine asks if you want X to start automatically every time you system boots. This can make problem solving difficult and results in less control over the system. You can always start the GUI with **startx** from the command line.
    - By default, Xorg will use a standard VESA driver to run your X Window system. You can attempt to get a more optimum configuration after the installation by running **X -configure**, which will write a new configuration file with settings tailored more for your hardware. This will create a file called *xorg.conf.new* which can then be copied to */etc/X11/xorg.conf.*
    - I would suggest you use XFCE as you desktop manager. Feel free to use others, but XFCE will provide a clean, uncluttered interface.
    - You select XFCE as your desktop during the Slackware installation by choosing "*xinitrc.xfce"* during the X setup portion. You can try other window managers by running the command **xwmconfig** and selecting a different one.
- Boot Method (the Boot loader…selects the OS to boot)
    - LILO or GRUB.
        - LILO is the default for Slackware. Some people find GRUB more flexible and secure. GRUB can be installed later, if you like.
        - Usually select the option to install LILO to the master boot record (MBR). The presence of other boot loaders (as provided by other operating systems) determines where to install LILO or GRUB.
        - The boot loader contains the code that points to the kernel to be booted. Check http://www.tldp.org for "multiOS" and "multiboot" How-To documents.
- Create a user name for yourself – avoid using root exclusively.
- For more information, check the file CHANGES_AND_HINTS.TXT on the install CD, or at: http://slackware.osuosl.org/slackware-12.1/CHANGES_AND_HINTS.TXT
  This file is loaded with useful hints and changes of interest from one release to another.

Linux is a multiuser system. It is designed for use on networks (remember, it is based on Unix). The "root" user is the system administrator, and is created by default during installation. Exclusive use of the "root" login is DANGEROUS. Linux assumes that "root" knows what he or she is doing and allows "root" to do anything he or she wants, including destroy the system. Create a new user. Don't log in as "root" unless you must. Having said this, much of the work done for forensic analysis must be done as "root" to allow access to raw devices and system commands.

Desktop Environment

When talking about forensic suitability, your choice of desktop system can make a difference. First of all, the term “desktop environment” and “window manager” are NOT interchangeable. Let's briefly clarify the components of a common Linux GUI.

- *X Window* – This is the basic GUI environment used in Linux. Commonly referred to as “X”, it is the application that provides the GUI framework, and is NOT part of the OS. X is a client / server program with complete network transparency.
- *Window Manager* – This is a program that controls the appearance of windows in the X Window system, along with certain GUI behaviors (window focus, etc.). Examples are Kwin, Metacity, XFWM, Enlightenment, etc.
- *Desktop Environment* – A combination of Window Manager and a consistent interface that provides the overall desktop experience. Examples are XFCE, GNOME, KDE, etc.
  - The default Window Manager for KDE is Kwin.
  - The default Window Manager for GNOME is Metacity
  - The default Window Manager for XFCE is XFWM.

These defaults can be changed to allow for preferences in speed and resource management over the desire for “eye-candy”, etc. You can also elect to run a Window Manager without a desktop environment. For example, the Enlightenment Window Manager is known for it's eye-candy and can be run standalone, with or without KDE or GNOME, etc.

Slackware no longer comes with GNOME as an option, though it can be installed like any other application. During the base Slackware installation, you will be given a choice of KDE, XFCE, and some others. I would like to suggest XFCE. It provides a cleaner interface for a beginner to learn on. It is leaner and therefore less resource intensive. You still have access to many KDE utilities, if you elected to install KDE during package selection. You can install more than one desktop and switch between them, if you like. The easiest way to switch is with the **xwmconfig** command.

The Linux Kernel: Versions and Issues

The Linux kernel is the “brain” of the system. It is the base component of the Operating System that allows the hardware to interact with and manage other software and system resources.

In December of 2003, the Linux 2.6 kernel was released. This was another milestone in the Linux saga, and all of the newer “mainstream” distribution versions are based on the 2.6 kernel. Many of the changes in 2.6 over the previous 2.4 are geared toward enterprise use and scalability. The newer kernel release also has a number of infrastructure changes that have a significant impact on Linux as a forensic platform. For example, there is enhanced support for USB and a myriad of other external devices. Read up on *udev* for more information one one such change [1]. We will very briefly discuss udev later in this section.

As with all forensic tools, we need to have a clear view of how any kernel version will interact with our forensic platforms and subject hardware. Almost all current distributions of Linux already come with a 2.6 kernel installed by default. Slackware 12 has also moved to the 2.6 kernel series (2.6.24.5 in 12.1).

Previous versions of this document suggested using an “older” (but updated) version of the kernel (2.4 series) to account for infrastructure changes in newer kernel versions that could adversely affect Linux employed as a forensic platform. This version of the Linux Forensic Practitioner's Guide has departed from that philosophy and we now use a distribution with a 2. 6 kernel by default. Still, it is both interesting and important to understand the implications of kernel choice on a forensic platform. So while we have moved on to the 2.6 kernel, we will still cover the differences and caveats to using a modern kernel.

Prior to the 2.6 series kernel, the developers maintained 2 separate kernel “branches”. One was for the “stable” kernel, and the other was for “testing”. Once released, the stable kernel was updated with bug fixes and was considered a solid production kernel. The other kernel branch was the testing branch and was used to incorporate innovations and updates to the kernel infrastructure. The stable kernel had an even numbered secondary point release, and the testing branch had an odd numbered secondary point release.

Stable branch	*Testing Branch*
2.0	*2.1*
2.2	*2.3*
2.4	*2.5*
2.6	*??*

[1] http://www.kernel.org/pub/linux/utils/kernel/hotplug/udev.html

The development of the 2.5 test kernel series resulted in the “stable” 2.6 series. Many of the improvements, once deemed stable, were “back ported” to the 2.4 kernel. As a result, the 2.4 series is still considered modern and supports much of the newer hardware currently in use.

So, what were the initial reservations about adhoc adoption of the 2.6 kernel in forensics, even though it's considered stable? You will notice from the chart above that there is no current 2.7 testing branch. The current kernel development scheme does not utilize a testing branch. This means that “new innovations” and changes to kernel infrastructure get wrapped directly into 2.6 kernel updates. As a result, critical upgrades within the 2.6 kernel series have a potential to break existing applications. There were many in the Linux community (even outside of computer forensics) that saw the 2.6 kernel as a fine system for desktop computers, but did not consider using it in a production environment. Again, this does NOT mean that it was not suitable for forensics, just that it required more testing and careful configuration with the addition of more cutting edge features.

Of equal importance in selecting a Linux kernel for forensic use was the interface that the kernel provides between the hardware and the end user. The 2.6 kernel includes a number enhancements that are designed specifically to improve the overall Linux experience on the desktop. These enhancements, if not properly configured and controlled, can result in a loss of user control over devices, one of the primary reasons for using Linux for forensics in the first place. Such obstacles can be overcome through proper configuration, but rigorous testing, as with all forensic applications, is required. Knowing what services to disable, and what affect this will have on the entire system is imperative. While a complete discussion of these requirements is largely beyond the scope of this guide, we will cover basic configuration in later sections.

So we have finally arrived at a point where the 2.6 kernel is mainstream and we will be using it in our forensic environment. The key to safe use (this goes for ANY operating system) is knowledge of your environment and proper testing. Please keep that in mind. You MUST understand how your hardware and software interact with any given operating system before using it in a “production” forensic analysis.

One of the greatest strengths Linux provides is the concept of “total control”. This requires thorough testing and understanding. Don't lose sight of this in pursuit of an “easy” desktop experience.

Configuring Slackware 12: 2.6 kernel considerations

So, we've discussed the differences between the 2.4 and the 2.6 kernel. There are infrastructure changes and "enhancements" to the 2.6 kernel that can be more of a challenge to configure for a Linux beginner looking for a stable and sound forensic platform.

In this section, we will focus on the minimum configuration requirements for creating a sound forensic environment under current Linux distributions using the 2.6 kernel. We will briefly discuss device node management (*udev*), hardware abstraction (*HAL*) and message bus (*d-bus*) daemons, and the desktop environment. In simplified terms, it is these components that create the most obvious problems for forensic suitability in the most current Linux distributions. The good news is that, being Linux, the user has very granular control over these services. The control that we love having with Linux is still there, we just need to grab some of it back from the kernel (or the desktop, as the case may be).

udev

Starting with kernel version 2.6.13, Linux device management was handed over to a new system called udev. Traditionally, the device nodes (files representing the devices, located in the */dev* directory) used in previous kernel versions were static, that is they existed at all times, whether in use or not[2]. For example, on a system with static device nodes we may have a primary SATA hard drive that is detected by the kernel as */dev/sda*. Since we have no IDE drives, no drive is detected as */dev/hda*. But when we look in the */dev* directory we see static nodes for all the possible disk and partition names for */dev/hda*. The device nodes exist whether or not the device is detected.

In the new system, udev creates device nodes "on the fly". The nodes are created as the kernel detects the device and the */dev* directory is populated in real time. In addition to being more efficient, udev also runs in user space. One of the benefits of udev is that it provides for "persistent naming". In other words, you can write a set of rules (For a nice explanation of udev rules, see: http://reactivated.net/writing_udev_rules.html) that will allow udev to recognize a device based on individual characteristics (serial number, manufacturer, model, etc.). The rule can be written to create a user-defined link in the */dev* directory, so that for example, my thumb drive can always be accessed through an arbitrary device node name of my choice, like */dev/my-thumb*, if I so choose. This means that I don't have to search through USB device nodes to find the correct device name if I have more than one external storage device connected.

[2]We will not cover Devfs, a device management system that used dynamic nodes prior to udev.

Udev is required for current 2.6 kernels. On Slackware, it runs as a daemon from the startup script */etc/rc.d/rc.udev*. We will discuss these startup scripts in more detail later in this document. We will not do any specific configuration for udev on our forensic computers at this time. We discuss it here simply because it is a major change in device handling in the 2.6 kernel. Udev does NOT involve itself in auto mounting or otherwise interacting with applications. It simply provides a hardware to kernel interface.

Hardware Abstraction Layer

HAL refers to the Hardware Abstraction Layer. The HAL daemon maintains information about devices connected to the system. In effect, HAL acts as a “middle man” for device detection, in that it organizes device information in a uniform format accessible to applications that want to either access or react to a change is the status of a device (plugged in or unplugged, etc.). The information that HAL makes available is object specific and provides far more detail than normal kernel detection allows. As a result, applications that receive information about a device from HAL can react in context. HAL and udev are not connected, and operate independently of one another. Where HAL describes a device in detail, for use by applications, udev simply manages device nodes. In Slackware 12, HAL is run as a daemon from */etc/rc.d/rc.hald*. See the section titled “Service Startup Scripts” in Chapter III for more information on rc scripts and how to stop the service from auto-starting.

d-bus

The system message bus, or *d-bus*, provides a mechanism for applications to exchange information. For our purposes here, we will simply state that d-bus is the communication channel used by HAL to send its information to applications. In Slackware 12, d-bus is run as a daemon from */etc/rc.d/rc.messagebus*.

With some very fine configuration, it's possible to have HAL and d-bus running and still maintain a sound forensic environment. For our purposes, we will turn HAL and d-bus off. We do this because exhaustive configuration is outside the scope of this document. We will make these adjustment in the section “File Permissions” on page 41. It has been noted that turning d-bus off is not strictly required (at this point). I suggest doing so for the sake of safety. I urge you to test your own configurations.

2.6 Kernel and Desktops

One of the considerations when discussing Desktop Environments is its integration with the HAL and d-bus services to allow for desktop auto-mounting of removable media. KDE and GNOME are heavily integrated with HAL/d-bus and users need to be aware of how to control this undesired behavior in a forensic environment. Equally important is how to deal with instability caused when expected messages from the OS are not received by a polling application.

XFCE is a lighter weight (read: lighter on resources) desktop. And although XFCE is also capable of integration with HAL and d-bus, it allows for easier control of removable media on the desktop (search for thunar-volman). While KDE and GNOME also allow for control of auto-mounting through configuration dialogs, they are far more tightly integrated and arguably more complex.

"Rolling your own" - The Custom Kernel

"Every forensic examiner should compile his own kernel, just like every Jedi builds his own lightsaber."
-"The" Cory Altheide

At some point during your Linux education, you will want to learn how to recompile your kernel. Why? Well...the above quote puts it quite nicely. The kernel that comes with your distro of choice is often heavily patched, and is configured to work with the widest variety of hardware possible. This gives the stock distribution a better chance of working on a multitude of systems right out of the box. Note that the Slackware kernel's are nicely generic and quite suitable "out of the box" for forensic use. Also, be warned that user customized kernels make for difficult troubleshooting and you will often be asked to reproduce problems with a stock kernel before you can get specific support. This is simply a matter of defining a common denominator when addressing problems.

The actual steps for compiling a custom kernel are outside the scope of this document, and have been covered elsewhere[3]. The concepts, however are important for an overall understanding of how Linux works.

[3] A quick Internet search for "linux custom kernel compile" or the like will provide a good start. Throw in the word "forensic" for some more specific pointers.

As mentioned previously, the kernel provides the most basic interface between hardware and the system software and resource management. This includes drivers and other components that are actually small separate pieces of code that can either be compiled as “modules” or compiled directly in the kernel “image”.

There are two basic approaches to compiling a kernel. *Static* kernels are built so that all of the drivers and desired features are compiled into the single kernel image. *Modular* kernels are built such that drivers and other features can be compiled as separate “object” files that can be loaded and unloaded “on the fly” into a running system. More on handling kernel modules can be found in Section II of this document, under “Using Modules”.

In short, you might find yourself in need of a kernel recompile as a result of the fact that you require specific drivers or support that is not currently included in your distribution's default kernel configuration. Or, after becoming comfortable with Linux, you decide you want to try your hand at actually configuring your custom kernel simply because you want to make it more efficient or because you want to expand the support for hardware, file systems, or partition table types that you might come across during an investigation.

In any event, Forensics with Linux is all about control. Customizing your kernel configuration, while an advanced skill, is the most basic form of control you have in Linux (short of re-writing the source code itself). At some point, this is something you will want to educate yourself further on.

II. Linux Disks, Partitions and the File System

Disks

Linux treats its devices as files. The special directory where these "files" are maintained is *"/dev"*.

DEVICE:	FILE NAME:
• Floppy (a:)	/dev/fd0
• Hard disk (master, IDE-0)	/dev/hda
• Hard disk (slave, IDE-0)	/dev/hdb
• Hard disk (master, IDE-1)	/dev/hdc, etc.
• 1st SCSI hard disk (SATA, USB)	/dev/sda
• 2nd SCSI hard disk	/dev/sdb, etc.

Partitions

DEVICE:	FILE NAME:
1st Hard disk (master, IDE-0)	/dev/hda
• 1st Primary partition	/dev/hda1
• 2nd Primary partition	/dev/hda2, etc.
• 1st Logical drive (on ext'd part)	/dev/hda5
• 2nd Logical drive	/dev/hda6, etc.
2nd Hard disk (slave, IDE-0)	/dev/hdb
• 1st Primary partition	/dev/hdb1, etc.
CDROM (ATAPI) or 3rd disk (mstr, IDE-1)	/dev/hdc
1st SCSI disk (or SATA, USB, etc.)	/dev/sda
• 1st Primary partition	/dev/sda1, etc.

The pattern described above is fairly easy to follow. If you are using a standard IDE disk (or standard ATAPI CDROM drive), it will be referred to as *hdx* where the "x" is replaced with an "a" if the disk is connected to the primary IDE controller as master and a "b" if the disk is connected to the primary IDE controller as a slave device. In the same way, the IDE disks (or CDROM) connected to the secondary IDE controller as master and slave will be referred to as *hdc* and *hdd* respectively.

SCSI and Serial ATA (SATA) disks will be referred to as *sdx.* In the case of SCSI disks, they are assigned letters in the order in which they are detected. This includes USB and Firewire. For example, a primary SATA disk will be assigned *sda.* If you attach a USB disk or a thumb drive it will normally be detected as *sdb,* and so on.[4]

[4]You may run across older distributions that support *devfs* which uses a different naming scheme. Don't let this confuse you. The pattern described above is still supported through "links" for compatibility. See *http://www.atnf.csiro.au/people/rgooch/linux/docs/devfs.html* for more information.

The **fdisk** program can be used to create or list partitions on a supported device. This is an example of the output of **fdisk** on a dual boot system using the “list” option (*-l [dash “el”]*):

```
root@rock:~# fdisk -l /dev/hda

Disk /dev/hda: 60.0 GB, 60011642880 bytes
255 heads, 63 sectors/track, 7296 cylinders
Units = cylinders of 16065 * 512 = 8225280 bytes

   Device Boot    Start         End      Blocks   Id  System
/dev/hda1   *         1         654     5253223+   7  HPFS/NTFS
/dev/hda2           655        2478    14651280    7  HPFS/NTFS
/dev/hda3          2479        7296    38700585    5  Extended
/dev/hda5          2479        4303    14659281   83  Linux
/dev/hda6          4304        4366      506016   82  Linux swap
/dev/hda7          4367        7296    23535193+   c  W95 FAT32 (LBA)
```

fdisk –l /dev/hd*x* gives you a list of all the partitions available on a particular drive, in this case and IDE drive). Each partition is identified by its Linux name. The "boot flag" is indicated, and the beginning and ending cylinders for each partition is given. The number of blocks per partition is displayed. Finally, the partition "Id" and file system type are displayed. To see a list of valid types, run **fdisk** and at the prompt type "l" (the letter “el”). Do not confuse Linux **fdisk** with DOS **fdisk**. They are very different. The Linux version of **fdisk** provides for much greater control over partitioning.

Remember that the partition type identified in the last column, under “System” has *nothing* to do with the file system found on that partition. Do not rely on the partition type to determine the file system. On most normal systems, a type “c” (W95 FAT32) partition type will contain a FAT32 partition, but not always. Also, consider partitions of type 83 (Linux). Type 83 partitions can normally hold EXT2, EXT3, ReiserFS, or any number of other file system types. We will discuss file system identification later in this document.

BEFORE FILE SYSTEMS ON DEVICES CAN BE USED, THEY MUST BE MOUNTED! Any file systems on partitions you define during installation will be mounted automatically every time you boot. We will cover the mounting of file systems in the section that deals with Linux commands, after you have some navigation experience.

Keep in mind, that even what not mounted, *devices* can still be written to. Simply not mounting a file system does not protect it from being inadvertently changed through your actions.

Mounting file systems on some types of external devices, which we will come to later in this document, may require us to delve a little deeper into modules

Using modules – Linux Drivers

It's difficult to decide when to introduce modules to a new user. The concept can be a little confusing, but "out of the box" Linux distributions rely heavily on modules for device and file system support. For this reason, we will make an effort to get familiar with the concept early on.

As discussed in the previous section, modules are really just "drivers" that can be loaded and unloaded from the kernel dynamically. They are object files (*.ko for the 2.6 kernel) that contain the required driver code for the supported device or option. Modules can be used to provide support for everything from USB controllers and network interfaces to file systems.

The various modules available on your system are located in the */lib/modules/<KERNEL-VERSION>/* directory. Note that the current kernel version running on your system can be found using the command **uname -r**.

There are, in general, three ways that driver code is loaded in Linux:

- Driver code is compiled directly into the kernel. The code is part of the kernel image that is loaded when the computer boots. Supported devices are recognized and configured as the OS loads.
- Modules are loaded at boot time through the actions of *udev*, which handles "hotplug" events. After the kernel is loaded, *udev* "events" are triggered and the proper modules are automatically loaded. We will cover this in more detail in the chapter covering system startup. Recall that udev handles the device node management.
- Modules are manually loaded by the user, as needed.

In cases where the driver code is *not* automatically loaded, modules can be installed and removed from the system "on the fly" using the following commands (as root):

modprobe	-an intelligent module loader
rmmod	-to remove the module
lsmod	-to get a list of currently installed modules

For example, to get USB support for a USB thumb drive on some systems, you may need to load a couple of modules. With the USB device plugged in, we can install the needed modules (*ehci_hcd* for many USB 2.0 controllers, and *usb-storage* for the storage interface) with:

modprobe ehci_hcd (depending on your USB controller)
modprobe usb-storage

Note that while the module is named with a ".ko" extension, we do not include that in the insertion command.

We only need to install these drivers if the kernel does not have the support *compiled in*, or if the module is not loaded automatically. Note that on a stock Slackware 12.1 system, the support for USB is compiled into the kernel and loading modules is not needed.

So how would you know if you needed to load modules? To check and see if the modules are already loaded, you can use the **lsmod** command to look for the driver name. Use **grep** to show only lines with specific text. We will cover **grep** in far more detail later on.

```
root@rock:~# lsmod | grep ehci_hcd
root@rock:~#
```

In this case, the command returns nothing. This might indicate that the driver is not loaded **or** it might indicated that the driver is not a module, but is compiled directly into the kernel. I can check this using the **dmesg** command and **grep** as well. The **dmesg** command replays the system startup messages

```
root@rock:~# dmesg | grep ehci_hcd
ehci_hcd 0000:00:1d.7: EHCI Host Controller
ehci_hcd 0000:00:1d.7: new USB bus registered, assigned bus number 1
ehci_hcd 0000:00:1d.7: debug port 1
ehci_hcd 0000:00:1d.7: irq 20, io mem 0x80004000
ehci_hcd 0000:00:1d.7: USB 2.0 started, EHCI 1.00, driver 10 Dec 2004
```

The output of the above commands shows us that support for the USB 2.0 host controller is already loaded (as shown in the **dmesg** output), but not as a module (as shown in the **lsmod** output).

While this subject can be a bit daunting at first, just keep in mind that an attached device may or may not work on a given system until the proper module is installed. Knowing how to check for existing support, and how to insert a module if needed is important.

Device Recognition

Another common question arises when a user plugs a device in a Linux box and receives no feedback on how (or even if) the device was recognized. One easy method for determining how and if an inserted device is registered is to use the previously introduced **dmesg** command.

For example, if I plug a USB thumb drive into a Linux computer, and the computer is running a HAL enabled desktop, I may well see an icon appear on the desktop for the disk. I might even see a folder open on the desktop allowing me to access the files automatically. Obviously, on a system we are using as a forensic platform, we may want to minimize this sort of behavior (more on that later...).

So when there is no visible feedback, where do we look to see what device node was assigned to our disk (*/dev/sda*, */dev/sdb*, etc.)? How do we know if it was even detected? Again, this question is particularly pertinent to the forensic examiner, since we will likely configure our system to be a little less "helpful".

Plugging in the thumb drive and running the **dmesg** command provides me with the following output:

```
root@rock:~# dmesg
<previous output>
scsi 2:0:0:0: Direct-Access     SanDisk  U3 Titanium      2.16 PQ: 0
ANSI: 2
sd 2:0:0:0: [sda] 1994385 512-byte hardware sectors (1021 MB)
sd 2:0:0:0: [sda] Write Protect is off
sd 2:0:0:0: [sda] Mode Sense: 03 00 00 00
sd 2:0:0:0: [sda] Assuming drive cache: write through
sd 2:0:0:0: [sda] 1994385 512-byte hardware sectors (1021 MB)
sd 2:0:0:0: [sda] Write Protect is off
 sda: sda1
sd 2:0:0:0: [sda] Attached SCSI removable disk
scsi 2:0:0:1: CD-ROM            SanDisk  U3 Titanium      2.16 PQ: 0
ANSI: 2
sr0: scsi3-mmc drive: 8x/40x writer xa/form2 cdda tray
sr 2:0:0:1: Attached scsi CD-ROM sr0
usb-storage: device scan complete
```

The important information is in bold. Note that this particular thumb drive (a SanDisk U3) provides two parts, the storage volume with a single partition (*/dev/sda1*), and an emulated CDROM device which was detected as */dev/sr0*. SCSI CDROM devices are recognized as *srx* or *scdx*.

The File System

Like the Windows file system, the Linux file system is hierarchical. the "top" directory is referred to as "the root" directory and is represented by "/". Note that the following is not a complete list, but provides an introduction to some important directories.

```
/ (“root” not to be confused with “/root”)
        |_ bin
        |       |_ <files> ls, chmod, sort, date, cp, dd
        |_boot
        |       |_<files> vmlinuz, system.map
        |_ dev
        |       |_<devices> hd*, tty*, sd*, fd*, cdrom
        |_ etc
        |       |_X11
        |               |_ <files> XF86Config, X
        |       |_<files> lilo.conf, fstab, inittab, modules.conf
        |_ home
        |       |_barry (your user’s name is in here)
        |               |_<files> .bashrc, .bash_profile, personal files
        |       |_other users
        |_mnt
        |       |_cdrom
        |       |_floppy
        |       |_other temporary mount points
        |_media
        |       |_cdrom0
        |       |_dvd0
        |       |_other standard media mount points
        |_root
        |       |_<root user's home directory>
        |_sbin
        |       |_<files> shutdown, cfdisk, fdisk, insmod
        |_usr
        |       |_local
        |       |_lib
        |       |_man
        |_var
        |       |_log
```

On most Linux distributions, the directory structure is organized in the same manner. Certain configuration files and programs are distribution dependent, but the basic layout is similar to this.

Note that the directory "slash" (/) is opposite what most people are used to in Windows (\).

Directory contents can include:

- **/bin** -Common commands.
- **/boot** -Files needed at boot time, including the kernel images pointed to by LILO (the LInux LOader) or GRUB.
- **/dev** -Files that represent devices on the system. These are actually interface files to allow the kernel to interact with the hardware and the file system.
- **/etc** -Administrative configuration files and scripts.
- **/home** -Directories for each user on the system. Each user directory can be extended by the respective user and will contain their personal files as well as user specific configuration files (for X preferences, etc.).
- **/mnt** -Provides temporary mount points for external, remote and removable file systems.
- **/media** -Provides a standard place for users and applications to mount removable media. Part of the new File System Hierarchy Standard.
- **/root** -The root user's home directory.
- **/sbin** -Administrative commands and process control daemons.
- **/usr** -Contains local software, libraries, games, etc.
- **/var** -Logs and other variable file will be found here.

Another important concept when browsing the file system is that of *relative* versus *explicit* paths. While confusing at first, practice will make the idea second nature. Just remember that when you provide a pathname to a command or file, including a "/" in front means an *explicit* path, and will define the location *starting from the top level directory (root).* Beginning a pathname **without** a *"/"* indicates that your path *starts in the current directory* and is referred to as a *relative* path. More on this later.

One very useful resource for this subject is the File System Hierarchy Standard (FHS), the purpose of which is to provide a reference for developers and system administrators on file and directory placement. Read more about it at http://www.pathname.com/fhs/

III. The Linux Boot Sequence (Simplified)

Booting the kernel

The first step in the (simplified) boot up sequence for Linux is loading the kernel. The kernel image is usually contained in the */boot* directory. It can go by several different names…

- bzImage
- vmlinuz

Sometimes the kernel image will specify the kernel version contained in the image, i.e. *bzImage-2.6.24*. Very often there is a soft link (like a shortcut) to the most current kernel image in the */boot* directory. It is normally this soft link that is referenced by the boot loader, LILO (or GRUB).

The boot loader specifies the "root device" (boot drive), along with the kernel version to be booted. For LILO, this is all controlled by the file */etc/lilo.conf*. Each "*image*=" section represents a choice in the boot screen.

This is an example of a *lilo.conf* file[5]:

```
root@rock:~# cat /etc/lilo.conf
boot=/dev/hda
map=/boot/map
install=/boot/boot.b
prompt
timeout=50
image=/boot/bzImage  < - Defines the Linux kernel to boot
     label=linux            < - Menu choice in LILO
     root=/dev/hda3         < - Where the root file system is found
     read-only
other=/dev/hda1             < - Defines alternate boot option
    label=WinXP             < - Menu choice in LILO
    table=/dev/hda
```

In the case of GRUB, each section beginning with "title" is a choice for booting and can include Linux as well as other operating systems, including Windows. Note again the reference to the kernel location, and the "root device" (where the root file system is located). GRUB starts it's counting from 0, so where you see "*hd0,0*" it is referring to the first IDE disk, followed by the first partition. See the **info** or **man** page for GRUB.

[5] The actual */etc/lilo.conf* file on your system will be much more cluttered with comments (lines starting with a "#". Comments have been removed from this example for readability.

In the following GRUB example, there will be two different Linux kernel choices offered in the boot menu. They all use the same root file system, but differ in the kernel image loaded from the */boot* partition.

```
root@rock:~# cat /boot/grub/grub.conf
boot=/dev/hda
default=0
timeout=10
splashimage=(hd0,0)/boot/grub/splash.xpm.gz
title Linux (2.6.24)  <- “title” sections define a boot menu choice
    root (hd0,0)  <- “root” device (1st hard drive and 1st partition)
    kernel /boot/bzImage ro root=/dev/hda1 <- kernel to boot
title Linux-old (2.4.33)
    root (hd0,0)
    kernel /boot/bzImage-2.4.33 ro root=/dev/hda1
```

Once the system has finished booting, you can see the kernel messages that “fly” past the screen during the booting process with the command **dmesg.** We discussed this command a little when we talked about device recognition earlier. As previously mentioned, this command can be used to find hardware problems, or to see how a removable (or suspect) drive was detected, including its geometry, etc. The output can be piped through a paging viewer to make it easier to see (in this case, **dmesg** is piped through **less** on my Slackware system.):

```
root@rock:~# dmesg | less
Linux version 2.6.24.5-smp (root@midas) (gcc version 4.2.3) #2 SMP Wed
Apr 30 13
:41:38 CDT 2008
BIOS-provided physical RAM map:
 BIOS-e820: 0000000000000000 - 000000000009fc00 (usable)
 BIOS-e820: 000000000009fc00 - 00000000000a0000 (reserved)
 BIOS-e820: 00000000000f0000 - 0000000000100000 (reserved)
 BIOS-e820: 0000000000100000 - 000000001fff0000 (usable)
 BIOS-e820: 000000001fff0000 - 0000000020000000 (ACPI data)
 BIOS-e820: 00000000fffc0000 - 0000000100000000 (reserved)
0MB HIGHMEM available.
511MB LOWMEM available.
Entering add_active_range(0, 0, 131056) 0 entries of 256 used
<continues>
```

Initialization

The next step in the boot sequence starts with the program */sbin/init.* This program really has two functions:

- initialize the runlevel and startup scripts
- terminal process control (respawn terminals)

In short, the **init** program is controlled by the file */etc/inittab*. It is this file that controls your runlevel and the global startup scripts for the system.

Runlevel

The runlevel is simply a description of the system state. For our purposes, it is easiest to say that (for *Slackware*, at least – other systems, like *Fedora Core* will differ):

- runlevel 0 = shutdown
- runlevel 1 = single user mode
- runlevel 3 = full multiuser mode / text login
- runlevel 4 = full multiuser / X11 / graphical login[6]
- runlevel 6 = reboot

In the file */etc/inittab* you will see a line similar to:

id:3:initdefault:

```
root@rock:~#less /etc/inittab
#
# /etc/inittab: This file describes how the INIT process should set up
#                 the system in a certain run-level.
#
# Default runlevel.
id:3:initdefault:

# System initialization, (runs when system boots).
si:S:sysinit:/etc/rc.d/rc.S
<continues>
```

It is here that the default runlevel for the system is set. If you want a text login (which I would strongly suggest), set the above value to "*3*". This is the default for Slackware. With this default runlevel, you use **startx** to get to the X Window GUI system. If you want a graphical login, you would edit the above line to contain a "*4*".

[6] This is largely distribution dependent. In Fedora Core, run level 5 provides a GUI login. In Slackware, it's run level 4.

Global Startup Scripts

After the default run level has been set, *init* (via */etc/inittab*) then runs the following scripts:

- */etc/rc.d/rc.S* - handles system initialization, file system mount and check, PNP devices, etc.

- */etc/rc.d/rc.X* - where *X* is the run level passed as an argument by *init*. In the case of mulit-user (non GUI) logins (run level 2 or 3), this is *rc.M.* This script then calls other startup scripts (various services, etc.) by checking to see if they are "executable".
- */etc/rc.d/rc.local* - called from within the specific run level scripts, *rc.local* is a general purpose script that can be edited to include commands that you want started at bootup (sort of like *autoexec.bat*).
- */etc/rc.d/rc.local_shutdown* - This file should be used to stop any services that were started in *rc.local.*

Service Startup Scripts

Once the global scripts run, there are "service scripts" in the */etc/rc.d/* directory that are called by the various runlevel scripts, as described above, depending on whether the scripts themselves have "executable" permissions. This means that we can control the boot time initialization of a service by changing it's executable status. More on how to do this later. Some examples of service scripts are:

- */etc/rc.d/rc.inet1* - handles network interface initialization
- */etc/rc.d/rc.inet2* – handles network services start. This script organizes the various network services scripts, and ensures that they are started in the proper order.
- */etc/rc.d/rc. pcmcia* - starts PC card services.
- */etc/rc.d/rc.sendmail* – starts the mail server. Controlled by *rc.inet2.*
- */etc/rc.d/rc.sshd* – starts the OpenSSH server. Also controlled by *rc.inet2.*
- */etc/rc.d/rc. messagebus* - starts *d-bus* messaging services.
- */etc/rc.d/rc. hald* - starts hardware abstraction layer daemon services.
- */etc/rc.d/rc. udev* - populates the */dev* directory with device nodes, scans for devices, loads the appropriate kernel modules, and configures the devices.

Have a look at the */etc/rc.d* directory for more examples. Note that in a standard Slackware install, you directory listing will show executable scripts as green in color (in the terminal) and followed by an asterisk (*).

Again, this is Slackware specific. Other distributions differ (some differ greatly!), but the concept remains consistent. Once you become familiar with the process, it will make sense. The ability to manipulate startup scripts is an important step in your Linux learning process.

Bash

bash *(Bourne Again Shell)* is the default command shell for most Linux distros. It is the program that sets the environment for your command line experience in Linux. The functional equivalent in DOS would be *command.com*. There are a number of shells available, but we will cover **bash** here.

There are actually quite a few files that can be used to customize a user's Linux experience. Here are some that will get you started.

- */etc/profile* - This is the global **bash** initialization file for interactive login shells. Edits made to this file will be applied to all bash shell users. This file sets the standard system path, the format of the command prompt and other environment variables.
    - Note that changes made to this file may be lost during upgrades. Another method is to create an executable file in the directory */etc/profile.d*. Executable files placed in that directory are run at the end of */etc/profile*.
- */home/$USER/.bash_profile*[7] - This script is located in each user's home directory (*$USER*) and can be edited by the user, allowing him or her to customize their own environment. It is in this file that you can add aliases to change the way commands respond. Note that the dot in front of the filename makes it a "hidden" file.
- */home/$USER/.bash_history* – This is an exceedingly useful file for a number of reasons. It stores a set number of commands that have already been typed at the command line (default is 500). These are accessible through either "reverse shells" or simply by using the "up" arrow on the keyboard to scroll through the history of already-used commands. Instead of re-typing a command over and over again, you can access it from the history.
    - From the perspective of a forensic examiner, if you are examining a Linux system, you can access each user's (don't forget root) *.bash_history* file to see what commands were run from the command line. Remember that the leading "." in the file name signifies that it is a hidden file.

[7] In bash we define the contents of a variable with a dollar sign. $USER is a variable that represents the name of the current user. To see the contents of shell individual variables, use "echo $VARNAME".

Keep in mind that the default values for *./bash_history* (number of entries, history file name, etc.) can be controlled by the user(s). Read **man bash** for more detailed info.

The **bash** startup sequence is actually more complicated than this, but this should give you a starting point. In addition to the above files, check out */home/$USER/.bashrc.* The **man** page for **bash** is an interesting (and long) read, and will describe some of the customization options. In addition, reading the **man** page will give a good introduction to the programming power provided by **bash** scripting. When you read the **man** page, you will want to concentrate on the *INVOCATION* section for how the shell is used and basic programming syntax.

IV. Linux Commands

Linux at the terminal

Directory listing =

ls	list files.
ls –F	classifies files and directories.
ls –a	show all files (including hidden).
ls –l	detailed file list (long view).
ls –lh	detailed list (long, with "human readable" file sizes).

```
root@rock:~# ls -l
total 3984
drwxr-xr-x   3 root    root     4096 Feb 15  2004 Backup_config
drwxr-xr-x   2 root    root     4096 Jun 16 16:10 Desktop
drwx------   2 root    root     4096 Jan 27  2004 Documents
drwxr-xr-x   3 root    root     4096 Aug 10 14:26 VMware
-rw-r--r--   1 root    root      175 Sep 26  2003 investigator.bjg
-rwxrwx---   1 root    root     2740 Dec 15  2003 k.key
-rwxr-xr-x   1 root    root   107012 Nov 29  2003 scanModem
<continues>
```

We will discuss the meaning of each column in the **ls -l** output later in this document.

Change directory =

cd <dir>	change directory to <dir>.
cd	(by itself) shortcut back to your home directory.
cd ..	up one directory (note the space between "cd" and "..".
cd -	back to the last directory you were in.
cd /*dirname*	change to the specified directory. Note that the addition of the "/" in front of the directory implies an explicit (absolute) path, not a relative one. With practice, this will make more sense.
cd *dirname*	change to the specified directory. The lack of a "/" in front of the directory name implies a relative path meaning *dirname* is a subfolder of our current directory.

Copy

cp

cp *sourcefile destinationfile* copy a file.

Clear the Terminal

clear clears the terminal screen of all text and returns a prompt.

Move a file or directory

mv	
mv *sourcefile destinationfile*	move or rename a file.

Delete a file or directory

rm	
rm *filename*	deletes a file.
rm -r	recursively deletes all files in directories and subdirectories.
rmdir	remove directories.
rm -f	do not prompt for file removal

Display command help

man	
man *command*	displays a "manual" page for the specified command. Use "q" to quit. VERY USEFUL.

If you want to find information about a command called **find**, including its usage, options, output, etc., then you would use the "man page" for the command **find :**

```
root@rock:~# man find
FIND(1L)                                                    FIND(1L)

NAME
       find - search for files in a directory hierarchy

SYNOPSIS
       find [path...] [expression]

DESCRIPTION
       This manual page documents the GNU version of find.  find
searches the directory tree rooted at each given file name by
evaluating the  given expression from left to right, according to the
rules of precedence (see section OPERATORS), until the outcome is
known (the left hand side is false for and operations, true for or),
at which point find moves on to the next file name.
<continues>
```

Create a directory

mkdir	
mkdir *directoryname*	creates a directory. Again, remember the difference between a relative and explicit path here.

Display the contents of a file

cat or **more** or **less**

cat *filename* The simplest form of file display, **cat** streams the contents of a file to the standard output (usually the terminal). **cat** actually stands for "*concatenate*". This command can also be used to add files together (useful later on…). For example:

cat *file1 file2* > *file3*

Takes the contents of *file1* and *file2* and streams the output which is redirected to a single file, *file3*. This effectively adds the two files into one single file (the original files remain unchanged).

more *filename* displays the contents of a file one page at a time. Unlike its DOS counterpart, Linux **more** takes filenames as direct arguments.

less *filename* **less** is a better **more**. Supports scrolling in both directions, and a number of other powerful features. **less** is actually the GNU version of **more**, and on many systems you will find that **more** is actually a link to **less**. Use "**q**" to exit a **less** session.

Note that you can string together several options. For example:

ls -aF

```
bgrundy@rock:~/workdir $ ls -aF
./   .lntrc  arlist     dir1/  doc1@     rmscript*  workfiles/
../  .tschr  cpscript*  dir2/  mystuff/  topsc@
```

..will give you a list of all files (-a), including hidden files, and file/directory classification (-F, which shows "/" for directories, "*" for executables, and "@" for links).

Additional useful commands

grep - search for patterns.

grep ***pattern filename***

grep will look for occurrences of *pattern* within the file *filename*. **grep** is an extremely powerful tool. It has hundreds of uses given the large number of options it supports. Check the **man** page for more details. We will use **grep** in our forensic exercises later on.

find -allows you to search for a file (wild cards – actually "expressions" permitted). To look for your *fstab* file, you might try:

```
root@rock:~# find / -name fstab -print
/etc/fstab
```

This means "find, starting in the root directory (/), by name, *fstab* and print the results to the screen". **find** also allows you to search by file type or even file times (actually *inode* times). The power of the **find** command should not be underestimated. More on this tool later.

pwd -prints the present working directory to the screen. The following example shows that we are currently in the directory */root*.

```
root@rock:~# pwd
/root
```

file -categorizes files based on what they contain, regardless of the name (or extension, if one exists). Compares the file header to the "magic" file in an attempt to ID the file type. For example:

```
root@rock:~# file snapshot01.gif
snapshot01.gif: GIF image data, version 87a, 800 x 600
```

ps -list of current processes. Gives the process ID number (PID), and the terminal on which the process is running.

ps ax -shows all processes (**a**), and all processes without an associated terminal (**x**). Note the lack of a dash in front of the options. See the **man** page for info on this departure from our previous convention.

```
root@rock:~# ps ax
  PID TTY      STAT   TIME COMMAND
    1 ?        S      0:00 init [3]
    2 ?        SN     0:00 [ksoftirqd/0]
    3 ?        S<     0:00 [events/0]
    4 ?        S<     0:00 [khelper]
...
 1966 ?        Ss     0:00 /usr/sbin/syslogd -m 0
 1973 ?        Ss     0:00 /usr/sbin/klogd -c 3 -2
 2009 ?        Ss     0:00 /usr/sbin/acpid -c /etc/acpi/events
 2109 ?        Ss     0:00 /usr/sbin/cupsd
<continues>
```

strings -prints out the readable characters from a file. Will print out strings that are at least four characters long (by default)from a file. Useful for looking at data files without the originating program, and searching executables for useful strings, etc. More on this forensically useful command later.

chmod -changes the permissions on a file. (See the section in this document on permissions).

chown -changes the owner of a file in much the same way as **chmod** changes the permissions.

shutdown -this command MUST be used to shutdown the machine and cleanly exit the system. This is not DOS. Turning off the machine at the prompt is not allowed and can damage your file system (in some cases)[8]. You can run several different options here (check the man page for many more):

shutdown -r now -will reboot the system now (change to runlevel 6).

shutdown -h now -will halt the system. Ready for power down (change to runlevel 0).

[8] This has become much less of an issue with the newer journaled file systems used by Linux.

File Permissions

Files in Linux have certain specified file permissions. These permissions can be viewed by running the **ls -l** command on a directory or on a particular file. For example:

```
root@rock:~# ls -l myfile
-rwxr-xr-x   1 root    root        1643 Jan 19 23:23 myfile
```

If you look close at the first 10 characters, you have a dash (-) followed by 9 more characters. The first character describes the type of file. A dash (-) indicates a regular file. A "d" would indicate a directory, and "b" a special block device, etc.

First character of **ls -l** output:

-	=	regular file
d	=	directory
b	=	block device (SCSI or IDE disk)
c	=	character device (serial port)
l	=	link (points to another file or directory)

The next 9 characters indicate the file permissions. These are given in groups of three:

Owner	Group	Others
rwx	rwx	rwx

The characters indicate

r	=	read
w	=	write
x	=	execute

So for the above *myfile* we have

rwx r-x r-x

This gives the file owner read, write and execute permissions (rwx), but restricts other members of the owner’s group and users outside that group to only read and execute the file (r-x). Write access is denied as symbolized by the “-”.

Now back to the **chmod** command. There are a number of ways to use this command, including explicitly assigning r, w, or x to the file. We will cover the octal method here because the syntax is easiest to remember (and I find it most flexible). In this method, the syntax is as follows

chmod *octal filename*

octal is a three digit numerical value in which the first digit represents the owner, the second digit represents the group, and the third digit represents others outside the owner's group. Each digit is calculated by assigning a value to each permission:

read (r)	= 4
write (w)	= 2
execute (x)	= 1

For example, the file *filename* in our original example has an octal permission value of 755 (rwx =7, r-x =5, r-x=5). If you wanted to change the file so that the owner and the group had read, write and execute permissions, but others would only be allowed to read the file, you would issue the command:

chmod 774 *filename*

4(r)+2(w)+1(x)=7
4(r)+2(w)+1(x)=7
4(r)+0(-)+0(-) =4

A new long list of the file would show:

```
root@rock:~# chmod 774 myfile
root@rock:~# ls -l myfile
-rwxrwxr--   1 root    root        1643 Jan 19 23:23 myfile
```

*(rwx=**7**, rwx=**7**, r--=**4**)*

Let us look at a practical example of changing permissions. Earlier in this document we discussed the system initialization process. Part of that process is the execution of "*rc*" scripts that handle system services. Recall that the file */etc/inittab* invokes the appropriate run level scripts in the */etc/rc.d/* directory. In turn, these scripts test various service scripts in the */etc/rc.d/* directory for executable permissions. If the script is executable, it is invoked and the service is started. The test inside the *rc.M* (mulituser init script) for the PCMCIA service looks like this:

```
root@rock:~# cat /etc/rc.d/rc.M
...
if [ -x /etc/rc.d/rc.pcmcia ]; then
   . /etc/rc.d/rc.pcmcia start
<continues>
```

The code shown above is an "*if / then*" statement where the brackets signify the test and the *-x* checks for executable permissions. So it would read:

"if the file */etc/rc.d/rc.pcmcia* is executable, then execute the command **/etc/rc.d/rc.pcmcia start**".

Note that the rc scripts can have either **start**, **stop** or **restart** passed as arguments in most cases.

A look at the permissions of /etc/rc.d/rc.pcmcia shows that it is not executable, and so will not start at system initialization:

```
root@rock:~# ls -l /etc/rc.d/rc.pcmcia
-rw-r--r-- 1 root root 5090 2006-08-16 16:48 /etc/rc.d/rc.pcmcia
```

To change the executable permissions to allow PCMCIA services to start at boot time, I execute the following:

```
root@rock:~# chmod 755 /etc/rc.d/rc.pcmcia
root@rock:~# ls -l /etc/rc.d/rc.pcmcia
-rwxr-xr-x 1 root root 5090 2006-08-16 16:48 /etc/rc.d/rc.pcmcia*
```

The directory listing shows that I have changed the executable status of the script. Depending on your color terminal settings, you may also see the color of the file change and an asterisk appended to the name.

You can use this technique to go through your /etc/rc.d/ directory to turn off those services that you do not need. Since I'm not running a laptop, and don't need PCMCIA services or wireless support:

```
root@rock:~# chmod 644 /etc/rc.d/rc.pcmcia
root@rock:~# chmod 644 /etc/rc.d/rc.wireless
```

Since we are running a 2. 6 kernel on Slackware, and we want a forensically sound system in as simple a manner as possible here, you should do the same to the *rc.hald* (HAL) and *rc.messagebus* (d-bus) service scripts. This will prevent system messages from accessing and auto-mounting storage devices when they are detected. This does NOT prevent them from being detected...Just from being mounted and/or opened (normally by virtue of desktop software).

```
root@rock:~# chmod 644 /etc/rc.d/rc.hald
root@rock:~# chmod 644 /etc/rc.d/rc.messagebus
```

The changes will take effect next time you boot.

Metacharacters

The Linux command line (actually the **bash** shell in our case) also supports wild cards (metacharacters)

- * for multiple characters (including ".").
- ? for single characters.
- [ ] for groups of characters or a range of characters or numbers.

This is a complicated and *very* powerful subject, and *will* require further reading… Refer to "regular expressions" in your favorite Linux text, along with "globbing" or "shell expansion". There are important differences that can confuse a beginner, so don't get discouraged by confusion over what "*" means in different situations.

Command Hints

1. Linux has a history list of previously used commands (stored in the file named *.bash_history* in your home directory). Use the keyboard arrows to scroll through commands you've already typed.
2. Linux supports command line editing. You can used the cursor to navigate a previous command and correct errors.
3. Linux commands and filenames are CASE SENSITIVE.
4. Learn output redirection for *stdout* and *stderr* (">" and "2>"). More on this later.
5. Linux uses "/" for directories, DOS uses "\".
6. Linux uses "-" for command options, DOS uses "/".
7. Use "**q**" to quit from **less** or **man** sessions.
8. To execute commands in the current directory (if the current directory is not in your PATH), use the syntax "*./command*". This tells Linux to look in the present directory for the command. Unless it is explicitly specified, the current directory is NOT part of the normal user path, unlike DOS.

Pipes and Redirection

Like DOS, Linux allows you to redirect the output of a command from the standard output (usually the display or "console") to another device or file. This is useful for tasks like creating an output file that contains a list of files on a mounted volume, or in a directory. For example:

```
root@rock:~# ls -al > filelist.txt
```

The above command would output a long list of all the files in the current directory. Instead of outputting the list to the console, a new file called "*filelist.txt*" will be created that will contain the list. If the file "*filelist.txt*" already existed, then it will be overwritten. Use the following command to **append** the output of the command to the existing file, instead of over-writing it:

```
root@rock:~# ls -al >> filelist.txt
```

Another useful tool similar to that available on DOS is the *command pipe*. The command pipe takes the output of one command and "pipes" it straight to the input of another command. This is an extremely powerful tool for the command line. Look at the following process list (partial output shown):

```
root@rock:~# ps ax
  PID TTY      STAT   TIME COMMAND
    1 ?        S      0:00 init [3]
    2 ?        SN     0:00 [ksoftirqd/0]
    3 ?        S<     0:00 [events/0]
    4 ?        S<     0:00 [khelper]
    5 ?        S<     0:00 [kacpid]
   26 ?        S<     0:00 [kblockd/0]
   36 ?        S<     0:00 [vesafb]
   45 ?        S      0:00 [pdflush]
   46 ?        S      0:00 [pdflush]
   48 ?        S<     0:00 [aio/0]
 2490 tty1     S      0:00 bash
 3287 pts/0    Ss     0:00 -bash
 3325 pts/0    R+     0:00 ps ax
```

What if all you wanted to see were those processes ID's that indicated a bash shell? You could "pipe" the output of **ps** to the input of **grep**, specifying "bash" as the pattern for **grep** to search. The result would give you only those lines of the output from **ps** that contained the pattern "bash".

```
root@rock:~# ps ax | grep bash
2490 tty1     S      0:00 bash
3287 pts/0    Ss     0:00 -bash
```

A little later on we will cover using pipes on the command line to help with analysis.

Stringing multiple powerful commands together is one the most useful and powerful techniques provided by Linux for forensic analysis. This is one of the single most important concepts you will want to learn if you decide to take on Linux as a forensic tool. With a single command line built from multiple commands and pipes, you can use several utilities and programs to boil down an analysis **very** quickly.

The Super User

If Linux gives you an error message "*Permission denied*", then in all likelihood you need to be "root" to execute the command or edit the file, etc. You don't have to log out and then log back in as "root" to do this. Just use the **su** command to give yourself root powers (assuming you know root's password). Enter the password when prompted. You now have root privileges (the system prompt will reflect this). When you are finished using your **su** login, return to your original login by typing **exit**. Here is a sample **su** session:

```
bgrundy@rock:~$ whoami
bgrundy
bgrundy@rock:~$ su -
Password:<enter root password>
root@rock:~# whoami
root
root@rock:~# exit
logout
bgrundy@rock:~$
```

Note that the "-" after **su** allows Linux to apply root's environment (including root's path) to your **su** login. So you don't have to enter the full path of a command. Actually, **su** is a "switch user" command, and can allow you to become any user (if you know the password), not just root.

A word of caution: Be VERY judicious in your use of the root login. It can be destructive. For simple tasks that require root permission, use **su** and use it sparingly.

V. Editing with Vi

There are a number of terminal mode (non-GUI) editors available in Linux, including ***emacs*** and ***vi***. You could always use one of the available GUI text editors in Xwindow, but what if you are unable to start X? The benefit of learning ***vi*** or ***emacs*** is your ability to use them from an xterm, a character terminal, or a **telnet** (use **ssh** instead!) session, etc. We will discuss ***vi*** here. (I don't do ***emacs*** :-)). ***vi*** in particular is useful, because you will find it on all versions of Unix. Learn ***vi*** and you should be able to edit a file on any Unix system.

The Joy of Vi

You can start ***vi*** either by simply typing **vi** at the command prompt, or you can specify the file you want to edit with **vi *filename***. If the file does not already exist, it will be created for you.

vi consists of two operating modes, *command* mode and *edit* mode. When you first enter ***vi*** you will be in command mode. Command mode allows you to search for text, move around the file, and issue commands for saving, save-as, and exiting the editor. Edit mode is where you actually input and change text.

In order to switch to edit mode, type either **a** (for append), **i** (for insert), or one of the other insert options listed on the next page. When you do this you will see "--Insert--" appear at the bottom of your screen (in most versions). You can now input text. When you want to exit the edit mode and return to command mode, hit the escape key.

You can use the arrow keys to move around the file in command mode. The **vi** editor was designed, however, to be exceedingly efficient, if not intuitive. The traditional way of moving around the file is to use the qwerty keys right under your finger tips. More on this below. In addition, there are a number of other navigation keys that make moving around in **vi** easier.

If you lose track of which mode you are in, hit the escape key twice. You should hear your computer beep and you will know that you are in command mode.

In current Linux distributions, vi is usually a link to some newer implementation of **vi**, such as **vim** (vi improved), or in the case of Slackware, **elvis**. If your distribution includes **vim**, it should come with a nice online tutorial. It is worth your time. Try typing **vimtutor** at a command prompt.

Work through the entire thing. This is the single best way to start learning **vi**. The navigation keys mentioned above will become clear if you use **vimtutor**.

Vi command summary

Entering Edit Mode *from* Command Mode:

a	=	append text (after the cursor)
i	=	insert text (directly under the cursor)
o (the letter “oh”)	=	open a new line under the current line
O (capital “oh”)	=	open a new line above the current line

Command (Normal) Mode:

0 (zero)	=	Move cursor to beginning of current line.
$	=	Move cursor to the end of current line.
x	=	delete the character under the cursor
X	=	delete the character before the cursor
dd	=	delete the entire line the cursor is on
:w	=	save and continue editing
:wq	=	save and quit (can use ZZ as well)
:q!	=	quit and discard changes
:w *filename*	=	save a copy to *filename* (“save as”)

The best way to save yourself from a messed up edit is to hit **<ESC>** followed by **:q!** That command will quit ***without*** saving changes.

Another useful feature in command mode is the string search. To search for a particular string in a file, make sure you are in command mode and type

/string

Where *string* is your search target. After issuing the command, you can move on to the next hit by typing "**n**".

vi is an extremely powerful editor. There are a huge number of commands and capabilities that are outside the scope of this guide. See **man vi** for more details. Keep in mind there are chapters in books devoted to this editor. There are even a couple of books devoted to ***vi*** alone.

VI. Mounting File Systems

There is a long list of file system types that can be accessed through Linux. You do this by using the **mount** command. Linux has a couple of special directories used to **mount** file systems to the existing Linux directory tree. One directory is called */mnt*. It is here that you can dynamically attach new file systems from external (or internal) storage devices that were not mounted at boot time. Typically, the */mnt* directory is used for *temporary* mounting. Another available directory is */media*, which provides a standard place for users and applications to mount removable media. Actually you can **mount** file systems anywhere (not just on */mnt* or */media*), but it's better for organization. Since we will be dealing with mostly temporary mounting of various file systems, we will use the */mnt* directory for most of our work. Here is a brief overview.

Any time you specify a mount point you must first make sure that that directory exists. For example to mount a floppy under */mnt/floppy* you must be sure that */mnt/floppy* exists. After all, suppose we want to have a CDROM and a floppy mounted at the same time? They can't both be mounted under */mnt* (you would be trying to access two file systems through one directory!). So we create directories for each device’s file system under the parent directory */mnt*. You decide what you want to call the directories, but make them easy to remember. Keep in mind that until you learn to manipulate the file */etc/fstab* (covered later), only root can mount and unmount file systems.

Newer distributions usually create mount points for *floppy* and *cdrom* for you, but you might want to add others for yourself (mount points for subject disks or images, etc. like */mnt/data* or */mnt/analysis*):

```
root@rock:~# mkdir /mnt/analysis
```

The Mount Command

The "**mount**" command uses the following syntax:

mount -t <*filesystem*> -o <*options*> <device> <*mountpoint*>

Example: Reading a DOS / Windows floppy

- Insert the floppy and type:

```
root@rock:~# mount -t vfat /dev/fd0 /mnt/floppy
```

Now change to the newly mounted file system (this assumes that the directory */mnt/floppy* already exists. If not, create it)*:*

```
root@rock:~# cd /mnt/floppy
```

You should now be able to navigate the floppy as usual. When you are finished, EXIT OUT of the */mnt/floppy* directory, and unmount the file system with:

```
root@rock:~# umount /mnt/floppy
```

- Note the proper command is ***u*mount**, not ***un*mount**. This cleanly unmounts the file system. DO NOT remove the disk OR SWAP the disk until it is unmounted.
- If you get an error message that says the file system cannot be unmounted because it is busy, then you most likely have a file open from that directory, or are using that directory from another terminal. Check all your xterms and virtual terminals and make sure you are no longer in the mounted directory.

Example: Reading a CDROM

- Insert the CDROM and type:

```
root@rock:~# mount -t iso9660 /dev/cdrom /mnt/cdrom
```

- Now change to the newly mounted file system:

```
root@rock:~# cd /mnt/cdrom
```

- You should now be able to navigate the CD as usual.
- When you are finished, EXIT OUT of the */mnt/cdrom* directory, and unmount the file system with:

```
root@rock:~# umount /mnt/cdrom
```

If you want to see a list of file systems that are currently mounted, just use the **mount** command without any arguments or parameters. It will list the mount point and file system type of each device on system, along with the mount options used (if any).

```
root@rock:~# mount
/dev/hda5 on / type ext3 (rw,noatime)
none on /proc type proc (rw)
/dev/hda7 on /mnt/data type vfat (rw)
/dev/fd0 on /mnt/floppy type vfat (ro,noexec,noatime)
```

The ability to mount and unmount file systems is an important skill in Linux. There are a large number of options that can be used with **mount** (some we will cover later), and a number of ways the mounting can be done easily and automatically. Refer to the **mount info** or **man** pages for more information.

The file system table (/etc/fstab)

It might seem like "**mount -t iso9660 /dev/cdrom /mnt/cdrom**" is a lot to type every time you want to mount a CD. One way around this is to edit the file */etc/fstab* ("file system table"). This file allows you to provide defaults for your mountable file systems, thereby shortening the commands required to mount them. My */etc/fstab* looks like this:

```
root@rock:~# cat /etc/fstab
/dev/sda3           /           ext3    noauto,noatime  1 1
/dev/sda2           none        swap    sw              0 0
/dev/sda1           /boot       ext3    defaults        1 2
/dev/cdrom          /mnt/cdrom  iso9660 noauto,users,ro 0 0
/dev/sda4           /mnt/data   vfat    rw,users        0 0
none                /proc       proc    defaults        0 0
/dev/fd0            /mnt/floppy vfat    noauto,rw,users 0 0
```

The columns are:
<device> <mount point> <fstype> <default options>

With this */etc/fstab*, I can mount a floppy or CD by simply typing:

```
root@rock:~# mount /mnt/floppy
```

or

```
root@rock:~# mount /mnt/cdrom
```

The above **mount** commands look incomplete. When not enough information is given, the **mount** command will look to */etc/fstab* to fill in the blanks. If it finds the required info, it will go ahead with the mount.

Note the "user" entry in the options column for some devices. This allows non-root users to mount the devices. Very useful. To find out more about available options for */etc/fstab*, enter **info fstab** at the command prompt.

Also keep in mind that default Linux installations will often create */mnt/floppy* and */mnt/cdrom* for you already. After installing a new Linux system, have a look at */etc/fstab* to see what is available for you. If what you need isn't there, add it.

VII. Linux and Forensics

Included Forensic Tools

Linux comes with a number of simple utilities that make imaging and basic analysis of suspect disks and drives comparatively easy. These tools include:

- **dd -**command used to copy from an input file or device to an output file or device. Simple bitstream imaging.
- **sfdisk and fdisk -**used to determine the disk structure.
- **grep -**search files (or multiple files) for instances of an expression or pattern.
- **The loop device -**allows you to associate regular files with device nodes. This will then allow you to mount a bitstream image without having to rewrite the image to a disk.
- **md5sum and sha1sum -**create and store an MD5 or SHA hash of a file or list of files (including devices).
- **file -**reads a file's header information in an attempt to ascertain its type, regardless of name or extension.
- **xxd -** command line hexdump tool. For viewing a file in hex mode.

Following is a *very* simple series of steps to allow you to perform an easy practice analysis using the simple Linux tools mentioned above. All of the commands can be further explored with "**man *command***". For simplicity we are going to use a floppy with a FAT file system. Again, this is just an introduction to the basic commands. These steps can be far more powerful with some command line tweaking.

Analysis organization

Having already said that this is just an introduction, most of the work you will do here can be applied to actual casework. The tools are standard Linux tools, and although the example shown here is *very* simple, it can be extended with some practice and a little (ok, a lot) of reading. The practice floppy (in raw image format from a simple **dd**) for the following exercise is available at:

http://www.LinuxLEO.com/Files/practical.floppy.dd

Of course, as has been pointed out to me on numerous occasions in the last few years, floppy disks are largely a thing of the past. They are nice in that they have a standard size, make for a small and very manageable image for introductory practice, and provide a consistent physical interface (when they are present). Future versions of this document will likely do away with the floppy image altogether, in favor of more modern media (even for the basic exercise). But for the mean time, just bear with me and follow along. You don't need a floppy drive to download and analyze the image...if you don't have one, you'll just have to do without writing the image to a physical disk. At this point, understanding the concepts is good enough.

Once you download the floppy image, put a blank floppy disk in your drive and create the practice floppy with the following command (covered in detail later):

```
root@rock:~# dd if=practical.floppy.dd of=/dev/fd0
```

The output of various commands and the amount of searching we will do here is limited by the scope of this example and the amount of data on a floppy. When you actually do an analysis on larger media, you will want to have it organized. Note that when you issue a command that results in an output file, that file will end up in your current directory, unless you specify a path for it.

One way of organizing your data would be to create a directory in your “home” directory for evidence and then a subdirectory for different cases. Since we will be executing these commands as *root*, the home directory is */root:*

```
root@rock:~# mkdir ~/evid
```

The tilde (~) in front of the directory name is shorthand for "home directory", so when I type *~/evid*, it is interpreted as *$HOME/evid*. If I am logged in as *root*, the directory will be created as */root/evid*. Note that if you are already in your home directory, then you don't need to type *~/*. Simply using **mkdir evid** will work just fine. We are being explicit for instructional purposes.

Directing all of our analysis output to this directory will keep our output files separated from everything else and maintain case organization. You may wish to have a separate drive mounted as */mnt/evid*.

For the purposes of this exercise, we will be logged in as *root*. I have mentioned already that this is generally a bad idea, and that you can make a mess of your system if you are not careful. Many of the commands we are utilizing here require root access (permissions on devices that you might want to access **should not** be changed to allow otherwise, and doing so would be far more complex than you think). So the output files that we create and the images we make will be found under */root/evid/*.

An additional step you might want to take is to create a special mount point for all subject file system analysis . This is another way of separating common system use with evidence processing.

```
root@rock:~# mkdir /mnt/analysis
```

Determining the structure of the disk

There are two simple tools available for determining the structure of a disk attached to your system. The first, **fdisk**, we discussed earlier using the **-l** option. Replace the "x" with the letter of the drive that corresponds to the subject drive. For example, if our subject disk is attached on the secondary IDE channel as the master disk, it will be seen as */dev/hdc*. A Serial ATA (SATA) disk will be */dev/sda* (or *sdb*, etc.) We can get the partition information on that disk with:

```
root@rock:~# fdisk -l /dev/hdc

Disk /dev/hdc: 60.0 GB, 60011642880 bytes
255 heads, 63 sectors/track, 7296 cylinders
Units = cylinders of 16065 * 512 = 8225280 bytes

   Device Boot    Start         End      Blocks   Id  System
/dev/hdc1   *         1         654     5253223+   7  HPFS/NTFS
/dev/hdc2           655        2478    14651280    7  HPFS/NTFS
/dev/hdc3          2479        7296    38700585    5  Extended
/dev/hdc5          2479        4303    14659281   83  Linux
/dev/hdc6          4304        4366      506016   82  Linux swap
```

We can redirect the output of this command to a file for later use by issuing the command as:

```
root@rock:~# fdisk -l /dev/hdc > ~/evid/fdisk.disk1
```

A couple of things to note here: The name of the output file (*fdisk.disk1*) is completely arbitrary. There are no rules for extensions. Name the file anything you want. I would suggest you stick to a convention and make it descriptive. Also note that since we identified an explicit path for the file name, therefore *fdisk.disk1* will be created in */root/evid*. Had we not given the path, the file would be created in the current directory (*/root*).

Also note that you can expect to see strange output if you use **fdisk** on a floppy disk. The **fdisk** command works by examining the partition table in the first sector (0) of a device. If there is no partition table there, such as on devices that house a single volume, it will still attempt to interpret the data and output garbage. Be aware of that if you attempt **fdisk** on the practice floppy (and some USB thumb drives). Try it on your hard drive instead to see sample output. Don’t use **fdisk** on the practice floppy. The output will just confuse you.

Creating a forensic image of the suspect disk

Make an image of the practice disk using basic **dd**. This is your standard forensic image of a suspect disk. Change to and execute the command from within the */root/evid/* directory:

```
root@rock:~# cd evid
root@rock:~/evid # dd if=/dev/fd0 of=image.disk1 bs=512
```

This takes your floppy device *(/dev/fd0*) as the input file (*if*) and writes the output file (*of*) called *image.disk1* in the current directory (*/root/evid/*). The **bs** option specifies the block size. This is really not needed for most block devices (hard drives, etc.) as the Linux kernel handles the actual block size. It’s added here for illustration, as it can be a useful option in many situations (discussed later).

For the sake of safety and practice, change the read-write permissions of your image to read-only (for what it's worth, I don't normally do this).

```
root@rock:~/evid # chmod 444 image.disk1
```

The **444** gives all users read-only access. If you are real picky, you could use **400.** Note that the owner of the file is the user that created it.

Now that you have created an image file, you can restore the image to another disk if you are interested in a "clone" of the original disk. Put another (blank) floppy in and type:

```
root@rock:~/evid # dd if=image.disk1 of=/dev/fd0 bs=512
```

This is the same as the first **dd** command, only in reverse. Now you are taking your image (the input file "*if*") and writing it to another disk (the output file "*of*") to be used as a backup or as a working copy for the actual analysis.

Note that using **dd** creates an exact duplicate of the physical device file. This includes all the file slack and unallocated space. We are not simply copying the logical file structure. Unlike many forensic imaging tools, **dd** does not fill the image with any proprietary data or information. It is a simple bit stream copy from start to end. This (in my ever-so-humble opinion) has a number of advantages, as we will see later.

Mounting a restored image

Mount the restored (cloned) working copy and view the contents. Remember, we are assuming this is a DOS formatted disk from a Win 98/95 machine.

```
root@rock:~/evid # mount -t vfat -o ro,noexec /dev/fd0 /mnt/analysis
```

This will mount your working copy (the new floppy you created from the forensic image) on "*/mnt/analysis*". The "**–o ro,noexec**" specifies the options **ro** (read-only) and **noexec** (prevents the execution of binaries from the mount point) in order to protect the disk from you, and your system (and mount point) from the contents of the disk. There are other useful mount options as well, such as **noatime**. See **man mount** for more details.

Now **cd** to the mount point (*/mnt/analysis*) and browse the contents. Having mounted the physical clone of our original, we are simply looking at the logical file system.

Be sure to unmount the disk when you finish.

```
root@rock:~/evid # umount /mnt/analysis
```

Mounting the image using the loopback device

Another way to view the contents of the image without having to restore it to another disk is to mount using the *loop* interface. Basically, this allows you to “mount” a file system within an image file (instead of a disk) to a mount point and browse the contents. Your Linux kernel must have *loop* either compiled as a module or compiled into the kernel for this to work. By default, Slackware 12 has the *loop* driver compiled into the kernel.

We use the same mount command and the same options, but this time we include the option “**loop**” to indicate that we want to use the *loop* device to mount the file system within the image file, and we specify a disk (partition) image rather than a disk device. Change to the directory where you created the image and type:

```
root@rock:~/evid # mount -t vfat -o ro,noexec,loop image.disk1 /mnt/analysis
```

Now you can change to */mnt/analysis* and browse the image as if it were a mounted disk! Use the **mount** command by itself to double check the mounted options.

When you are finished browsing, unmount the image file.

```
root@rock:~/evid # umount /mnt/analysis
```

File Hash

One important step in any analysis is verifying the integrity of your data both before after the analysis is complete. You can get a hash (CRC, MD5, or SHA) of each file in a number of different ways. In this example, we will use the SHA hash. SHA is a hash signature generator that supplies a 160-bit “fingerprint” of a file or disk. It is not feasible for someone to computationally recreate a file based on the SHA hash. This means that matching SHA signatures mean identical files.

We can get an SHA sum of a disk by changing to our evidence directory (i.e. */root/evid*) and running the following command (note that the following commands can be replaced with **md5sum** if you prefer to use the MD5 hash algorithm):

```
root@rock:~/evid # sha1sum /dev/fd0
```

or

```
root@rock:~/evid # sha1sum /dev/fd0 > sha.disk1
```

The redirection in the second command allows us to store the signature in a file and use it for verification later on. To get a hash of a raw disk (*/dev/hda, /dev/fd0*, etc.) the disk does NOT have to be mounted. We are hashing the device (the disk) not the file system. As we discussed earlier, Linux treats all objects, including physical disks, as *files*. So whether you are hashing a file or a hard drive, the command is the same.

We can get a hash of each file on the disk using the **find** command and an option that allows us to execute a command on each file found. We can get a very useful list of SHA hashes for every file on a disk by loop mounting the image again, and then changing to the */mnt/analysis* directory:

```
root@rock:~# mount -t vfat -o ro,noexec,loop image.disk1 /mnt/analysis
root@rock:~# cd /mnt/analysis
root@rock:/mnt/analysis #
```

Once we are in the */mnt/analysis* directory (as reflected by our prompt), we can now run a command that will find all the *regular* files on the file system at that mount point and run a hash on all those files:

```
root@rock:/mnt/analysis # find . -type f -exec sha1sum {} \; > ~/evid/sha.filelist
```

This command says "**find**, starting in the *current* directory (signified by the "**.**"), any regular file (**-type f**) and execute (**-exec**) the command **sha1sum** on all files found ({}). Redirect the output to *sha.filelist* in the *~/evid* directory (where we are storing all of our evidence files). Remember, the tilde (~) in front of the directory name is shorthand for "home", so *~/evid* is equivalent to */root/evid*. The "**\;**" is an escape sequence that ends the **–exec** command. The result is a list of files from our analysis mount point and their SHA hashes. Again, you can substitute the **md5sum** command if you prefer.

Have a look at the hashes by using the **cat** command to stream the file to standard output (in this case, our terminal screen):

```
root@rock:/mnt/analysis # cat /root/evid/sha.filelist
86082e288fea4a0f5c5ed3c7c40b3e7947afec11  ./Docs/Benchmarks.xls
81e62f9f73633e85b91e7064655b0ed190228108  ./Docs/Computer_Build.xml
0950fb83dd03714d0c15622fa4c5efe719869e48  ./Docs/Law.doc
7a1d5170911a87a74ffff8569f85861bc2d2462d  ./Docs/whyhack
63ddc7bca46f08caa51e1d64a12885e1b4c33cc9  ./Pics/C800x600.jpg
8844614b5c2f90fd9df6f8c8766109573ae1b923  ./Pics/bike2.jpg
4cf18c44023c05fad0de98ed6b669dc4645f130b  ./Pics/bike3.jpg
<continues>
```

You can also use Linux to do your verification for you. To verify that nothing has been changed on the original floppy, you can use the -c option with **sha1sum**. If the disk was not altered, the command will return "ok". Make sure the floppy is in the drive and type:

```
root@rock:/mnt/analysis # sha1sum -c /root/evid/sha.disk1
```

If the SHA hashes match from the floppy and the original SHA output file, then the command will return "OK" for */dev/fd0*. Remember that *sha.disk1* contains the hash for the physical disk. The same can be done with the list of file SHAs. Make sure the floppy file system is still mounted on */mnt/analysis,* change to that directory and issue the command:

```
root@rock:/mnt/analysis # sha1sum -c /root/evid/sha.filelist
./Docs/Benchmarks.xls: OK
./Docs/Computer_Build.xml: OK
./Docs/Law.doc: OK
./Docs/whyhack: OK
./Pics/C800x600.jpg: OK
./Pics/bike2.jpg: OK
./Pics/bike3.jpg: OK
./Pics/matrixs3.jpg: OK
./Pics/mulewheelie.gif: OK
./Pics/Stoppie.gif: OK
./arp.exe: OK
./ftp.exe: OK
./loveletter.virus: OK
./ouchy.dat: OK
./snoof.gz: OK
```

Again, the SHA hashes in the file will be compared with SHA sums taken from the floppy (at the mount point). If anything has changed, the program will give a "failed" message. Unchanged files will be marked "OK". This is the fastest way to verify the hashes. Note that the filenames start with "./". This indicates a *relative* path. Meaning that we must be in the same relative directory when we check the hashes, since that's where the command will look for the files.

The Analysis

You can now view the contents of the read-only mounted or restored disk or loop-mounted image. If you are running the X window system, then you can use your favorite file browser to look through the disk. In most (if not all) cases, you will find the command line more useful and powerful in order to allow file redirection and permanent record of your analysis. We will use the command line here.

We are also assuming that you are issuing the following commands from the proper mount point (*/mnt/analysis/*). If you want to save a copy of each command's output, be sure to direct the output file to your evidence directory (*/root/evid/)* using an explicit path.

Navigate through the directories and see what you can find. Use the **ls** command to view the contents of the disk. Again, you should be in the directory */mnt/analysis,* our working directory. The command in the following form might be useful:

```
root@rock:/mnt/analysis # ls -al
total 118
drwxr--r--   4 root root  7168 Dec 31  1969 .
drwxr-xr-x  13 root root  4096 Dec 21 14:20 ..
drwxr--r--   3 root root   512 Sep 23  2000 Docs
drwxr--r--   2 root root   512 Sep 23  2000 Pics
-rwxr--r--   1 root root 19536 Aug 24  1996 arp.exe
-rwxr--r--   1 root root 37520 Aug 24  1996 ftp.exe
-r-xr--r--   1 root root 16161 Sep 21  2000 loveletter.virus
-rwxr--r--   1 root root 21271 Mar 19  2000 ouchy.dat
-rwxr--r--   1 root root 12384 Aug  2  2000 snoof.gz
```

This will show all the hidden files (**-a),** give the list in long format to identify permission, date, etc. (**-l**). You can also use the **–R** option to list recursively through directories. You might want to pipe that through **less**.

```
root@rock: analysis # ls -alR | less
.:
total 118
drwxr--r--   4 root root  7168 Dec 31  1969 .
drwxr-xr-x  13 root root  4096 Dec 21 14:20 ..
drwxr--r--   3 root root   512 Sep 23  2000 Docs
drwxr--r--   2 root root   512 Sep 23  2000 Pics
...
./Docs:
total 64
drwxr--r--  3 root root   512 Sep 23  2000 .
drwxr--r--  4 root root  7168 Dec 31  1969 ..
-rwxr--r--  1 root root 17920 Sep 21  2000 Benchmarks.xls
<continues>
```

Note that we are looking at files on a FAT32 partition using Linux tools. Things like permissions can be a little misleading because of translations that may take place, depending on the file system, and omitted information. This is where some of our more advanced forensic tools come in later.

Use the space bar to scroll through the recursive list of files. Remember that the letter “q” will quit a paging session.

Making a List of All Files

Get creative. Take the above command and redirect the output to your evidence directory. With that you will have a list of all the files and their owners and permissions on the subject file system. This is a very important command. Check the **man** page for various uses and options. For example, you could use the **–i** option to include the inode (file “serial number”) in the list, the **–u** option can be used so that the output will include and sort by access time (when used with the **–t** option).

```
root@rock:/mnt/analysis # ls -laiRtu > ~/evid/access_file.list
```

You could also get a list of the files, one per line, using the **find** command and redirecting the output to another list file:

```
root@rock:/mnt/analysis # find . -type f > ~/evid/file.list.2
```

There is also the **tree** command, which prints a recursive listing that is more visual...It indents the entries by directory depth and colorizes the filenames (if the terminal is correctly set).

```
root@rock:/mnt/analysis # tree
|-- Docs
|   |-- Benchmarks.xls
|   |-- Computer_Build.xml
|   |-- Law.doc
|   |-- Private
|   `-- whyhack
|-- Pics
|   |-- C800x600.jpg
|   |-- Stoppie.gif
|   |-- bike2.jpg
|   |-- bike3.jpg
|   |-- matrixs3.jpg
|   `-- mulewheelie.gif
|-- arp.exe
|-- ftp.exe
|-- loveletter.virus
|-- ouchy.dat
`-- snoof.gz
3 directories, 15 files
```

Have a look at the above commands, and compare their output. Which do you like better? Remember the syntax assumes you are issuing the command from the */mnt/analysis* directory (use **pwd** if you don't know where you are).

Now use the **grep** command on either of lists created by the first two commands above for whatever strings or extensions you want to look for.

```
root@rock:/mnt/analysis # grep -i jpg ~/evid/file.list.2
```

This command looks for the pattern "jpg" in the list of files, using the filename extension to alert us to a JPEG file. The **-i** makes the **grep** command case insensitive. Once you get a better handle on **grep**, you can make your searches far more targeted. For example, specifying strings at the beginning or end of a line (like file extensions) using "^" or "$". The **grep man** page has a whole section on these "regular expression" terms.

Making a List of File Types

What if you are looking for JPEG's but the name of the file has been changed, or the extension is wrong? You can also run the command **file** on each file and see what it might contain.

file *filename*

The **file** command compares each file's header (the first few bytes of a raw file) with the contents of the "magic" file (can be found in */usr/share/magic,* or */etc/file/magic*, depending on the distribution). It then outputs a description of the file.

If there are a large number of files without extensions, or where the extensions have changed, you might want to run the **file** command on *all* the files on a disk (or in a directory, etc.). Remember our use of the **find** command's **-exec** option with **sha1sum**? Let's do the same thing with **file**:

```
root@rock:/mnt/analysis # find . -type f -exec file {} \; > ~/evid/filetype.list
```

View the resulting list with the **cat** command (or **less**), and if you are looking for images in particular, then use **grep** to specify that:

```
root@rock:/mnt/analysis # cat ~/evid/filetype.list
./Docs/Benchmarks.xls: Microsoft Installer
./Docs/Computer_Build.xml: gzip compressed data, from Unix
./Docs/Law.doc: Microsoft Installer
./Docs/whyhack: ASCII English text, with very long lines
./Pics/C800x600.jpg: JPEG image data, JFIF standard 1.02
./Pics/bike2.jpg: PC bitmap data, Windows 3.x format, 300 x 204 x 24
./Pics/bike3.jpg: PC bitmap data, Windows 3.x format, 317 x 197 x 24
./Pics/matrixs3.jpg: JPEG image data, JFIF standard 1.01
./Pics/mulewheelie.gif: PC bitmap data, Windows 3.x format, 425x328x24
./Pics/Stoppie.gif: GIF image data, version 87a, 1024 x 693
./arp.exe: MS-DOS exe PE for MS Windows (console) Intel 80386 32-bit
./ftp.exe: MS-DOS exe PE for MS Windows (console) Intel 80386 32-bit
./loveletter.virus: ASCII English text
./ouchy.dat: JPEG image data, JFIF standard 1.02
./snoof.gz: gzip compressed data, from Unix
```

The following command would look for the string "image" using the **grep** command on the file */root/evid/filetype.list*

```
root@rock:/mnt/analysis # grep image ~/evid/filetype.list
./Pics/C800x600.jpg: JPEG image data, JFIF standard 1.02
./Pics/matrixs3.jpg: JPEG image data, JFIF standard 1.01
./Pics/Stoppie.gif: GIF image data, version 87a, 1024 x 693
./ouchy.dat: JPEG image data, JFIF standard 1.02
```

Note that the file *ouchy.dat* does not have the proper extension, but it is still identified as a JPEG image. Also note that some of the images above do not show up in our **grep** list because their descriptions do not contain the word "image". There are two Windows Bitmap images that have .jpg extensions that do not end up in the **grep** list. We can fix this by either creating our own “images” magic file or by “tagging” the original file. We “tag” the original magic file by editing it to contain our own identifiers that we can then use **grep** to locate.

Viewing Files

For text files and data files, you might want to use **cat**, **more** or **less** to view the contents.

cat ***filename***
more ***filename***
less ***filename***

Be aware that if the output is not standard text, then you might corrupt the terminal output (type **reset** or **stty sane** at the prompt and it should clear up). It is best to run these commands in a terminal window in X so that you can simply close out a corrupted terminal and start another. Using the **file** command will give you a good idea of which files will be viewable and what program might best be used to view the contents of a file. For example, Microsoft Office documents can be opened under Linux using programs like OpenOffice.

Perhaps a better alternative for viewing unknown files would be to use the **strings** command. This command can be used to parse regular ASCII text out of any file. It’s good for formatted documents, data files (Excel, etc.) and even binaries (e.g. unidentified executables), which might have interesting text strings hidden in them. It might be best to pipe the output through **less.**

strings ***filename*** **| less**

Have a look at the contents of the practice disk on */mnt/analysis.* There is a file called *arp.exe.* What does this file do? We can’t execute it, and from using the **file** command we know that it’s an DOS/Windows executable. Run the following command (again, assuming you are in the */mnt/analysis* directory) and scroll through the output. Do you find anything of interest (hint: like a usage message)?

```
root@rock:/mnt/analysis # strings arp.exe | less
 l|}
<-t8</t4
t]Ph
t2Ph '
Ph!'
@SVW
wR9U
wM9U
wH9U
SVWj
...<continues>
inetmib1.dll
Displays and modifies the IP-to-Physical address translation tables
used by
address resolution protocol (ARP).
ARP -s inet_addr eth_addr [if_addr]
ARP -d inet_addr [if_addr]
ARP -a [inet_addr] [-N if_addr]
  -a    Displays current ARP entries by interrogating the current
        protocol data.  If inet_addr is specified, the IP and Physical
        addresses for only the specified computer are displayed.  If
        more than one network interface uses ARP, entries for each ARP
        table are displayed.
  -g            Same as -a.
<continues>
```

If you are currently running the X window system, you can use any of the graphics tools that come standard with whichever Linux distribution you are using. **gqview** is one graphics tool for the GNOME desktop that will display graphic files in a directory. Experiment a little. Other tools, such as **gthumb** for Gnome and **Konqueror** from the KDE desktop have a feature that will create a very nice html image gallery for you from all images in a directory.

Once you are finished exploring, be sure to unmount the floppy (or loop mounted disk image). Again, make sure you are not anywhere in the mount point when you try to unmount, or you will get the “busy” error. The commands will take you back to your home directory (using the tilde ~) and then unmount the loop mounted file system.

```
root@rock:/mnt/analysis # cd ~
root@rock:~# umount /mnt/analysis
```

Searching Unallocated and Slack Space for Text

Now let’s go back to the original image. The restored disk (or loop mounted disk image) allowed you to check all the files and directories (logical view). What about unallocated and slack space (physical view)? We will now analyze the image itself, since it was a bit for bit copy and includes data in the unallocated areas of the disk.

Let’s assume that we have seized this disk from a former employee of a large corporation. The would-be cracker sent a letter to the corporation threatening to unleash a virus in their network. The suspect denies sending the letter. This is a simple matter of finding the text from a deleted file (unallocated space).

First, change back to the directory in which you created the image, whether it was the root’s home directory, or a special one you created.

```
root@rock:~# cd /root/evid
root@rock:~/evid #
```

Now we will use the **grep** command to search the image for any instance of an expression or pattern. We will use a number of options to make the output of **grep** more useful. The syntax of **grep** is normally:

grep –options <pattern> <file-to-search>

The first thing we will do is create a list of keywords to search for. It’s rare we ever want to search evidence for a single keyword, after all. For our example, lets use “ransom”, “$50,000” (the ransom amount), and “unleash a virus”. These are some keywords and a phrase that we have decided to use from the original letter received by the corporation. Make the list of keywords (using **vi**) and save it as */root/evid/searchlist.txt.* Ensure that each string you want to search for is on a different line.

$50,000
ransom
unleash a virus

Make sure there are NO BLANK LINES IN THE LIST OR AT THE END OF THE LIST!! Now we run the **grep** command on our image:

```
root@rock:~/evid # grep -abif searchlist.txt image.disk1 > hits.txt
```

We are asking **grep** to use the list we created in “*searchlist.txt*” for the patterns we are looking for. This is specified with the “**-f *file***” option. We are telling **grep** to search *image.disk1* for these patterns, and redirect the output to a file called *hits.txt*, so we can record the output. The **–a** option tells **grep** to process the file as if it were text, even if it’s binary. The option **-i** tells **grep** to ignore upper and lower case. And the **-b** option tells **grep** to give us the byte offset of each hit so we can find the line in **xxd**. Earlier we mentioned the **grep man** page and the section it has on regular expressions. Please take the time to read through it and experiment.

Once you run the command above, you should have a new file in your current directory called *hits.txt*. View this file with **less** or **more** or any text viewer. Keep in mind that **strings** might be best for the job. Again, if you use **more** or **less**, you run the risk of corrupting your terminal if there are non-ASCII characters. We will simply use **cat** to stream the entire contents of the file to the standard output. The file *hits.txt* should give you a list of lines that contain the words in your *searchlist.txt* file. In front of each line is a number that represents the byte offset for that "hit" in the image file. For illustration purposes, the search terms are underlined, and the byte offsets are bold in the output below:

```
root@rock:~/evid # cat hits.txt
75441:you and your entire business ransom.
75500:I have had enough of your mindless corporate piracy and will no
longer stand for it. You will receive another letter next week.  It
will have a single bank account number and bank name.  I want you to
deposit $50,000 in the account the day you receive the letter.
75767:Don't try anything, and don't contact the cops.  If you do, I
will unleash a virus that will bring down your whole network and
destroy your consumer's confidence.
```

In keeping with our command line philosophy, we will use **xxd** to display the data found at each byte offset. **xxd** is a command line hex dump tool, useful for examining files. Do this for each offset in the list of hits. This should yield some interesting results if you scroll above and below the offsets.

```
root@rock:~/evid # xxd -s 75441 image.disk1 | less
00126b1: 796f 7520 616e 6420 796f 7572 2065 6e74  you and your ent
00126c1: 6972 6520 6275 7369 6e65 7373 2072 616e  ire business ran
00126d1: 736f 6d2e 0a0a 5468 6973 2069 7320 6e6f  som...This is no
00126e1: 7420 6120 6a6f 6b65 2e0a 0a49 2068 6176  t a joke...I hav
00126f1: 6520 6861 6420 656e 6f75 6768 206f 6620  e had enough of
0012701: 796f 7572 206d 696e 646c 6573 7320 636f  your mindless co
0012711: 7270 6f72 6174 6520 7069 7261 6379 2061  rporate piracy a
0012721: 6e64 2077 696c 6c20 6e6f 206c 6f6e 6765  nd will no longe
0012731: 7220 7374 616e 6420 666f 7220 6974 2e20  r stand for it.
<continues>
```

Please note that the use of **grep** in this manner is fairly limited. There are character sets that the common versions of **grep** do not support. So doing a physical search for a string on an image file is really only useful for what it does show you. In other words, negative results for a **grep** search of an image can be misleading. The strings or keywords may exist in the image in a form not recognizable to **grep** or **strings**.   There are tools that address this, and we will discuss some of them later.

VIII. Common Forensic Issues

Handling Large Disks

The example used in this text utilizes a file system on a floppy disk. What happens when you are dealing with larger hard disks? When you create an image of a disk drive with the **dd** command there are a number of components to the image. These components can include a boot sector, partition table, and the various partitions (if defined).

When you attempt to mount a larger image with the loop device, you find that the **mount** command is unable to find the file system on the disk. This is because **mount** does not know how to "recognize" the partition table. Remember, the **mount** command handles file systems, not disks (or disk images). The easy way around this (although it is not very efficient for large disks) would be to create separate images for each disk partition that you want to analyze. For a simple hard drive with a single large partition, you could create two images.

Assuming your suspect disk is attached as the master device on the secondary IDE channel:

```
root@rock:~# dd if=/dev/hdc of=image.disk.dd
```

...gets the entire disk.

```
root@rock:~# dd if=/dev/hdc1 of=image.part1.dd
```

...gets the first partition.

The first command gets you a full image of the entire disk (*hdc*) for backup purposes, including the boot record and partition table. The second command gets you the partition (*hdc1*). The resulting image from the second command can be mounted via the loop device.

Note that although both of the above images will contain the same file system with the same data, the hashes *will obviously not match.* Making separate images for each partition, however, is very inefficient.

One method for handling larger disks when using the loop device is to send the **mount** command a message to skip trying to mount the first 63 sectors of the image. These sectors are used to contain information (like the MBR) that is not part of a normal data partition. We know that each sector is

512 bytes, and that there are 63 of them. This gives us an offset of 32256 bytes from the start of our image to the first partition we want to mount. This is then passed to the **mount** command as an option, which essentially triggers the use of an available loop device to mount the specified file system:

```
root@rock:~# mount -t fstype -o loop,offset=32256 image.disk.dd /mnt/analysis
```

This effectively "jumps over" the first 63 sectors of the image and goes straight to the "boot sector" of the first partition, allowing the **mount** command to work properly. We will see other examples of this, and how to find the actual offset later in this document. It may not always be 63 sectors.

Now that we know about the issues surrounding the creation of large images from whole disks, what do we do if we run into an error? Suppose you are creating a disk image with **dd** and the command exits halfway through the process with a read error? We can instruct **dd** to *attempt* to read past the errors using the **conv=noerror** option. In basic terms, this is telling the **dd** command to ignore the errors that it finds, and attempt to read past them. When we specify the **noerror** option it is a good idea to include the **sync** option along with it. This will "pad" the **dd** output wherever errors are found and ensure that the output will be "synchronized" with the original disk. This may allow file system access and file recovery where errors are not fatal. Assuming that our subject drive is */dev/hdc,* the command will look something like:

```
root@rock:~# dd if=/dev/hdc of=image.disk.dd conv=noerror,sync
```

I would like to caution forensic examiners against using the **conv=noerror, sync** option, however. While **dd** is capable of reading past errors in many cases, it is not designed to actually *recover* any data from those areas. There are a number of tools out there that are designed specifically for this purpose. My current philosophy is that if you need to use **conv=noerror,sync**, then you are using the wrong tool. That is not to say it will not work as advertised (with some caveats), only that there are better options, or at least important considerations. We will discuss better options for error prone disks later in this document.

In addition to the structure of the images and the issues of image sizes, we also have to be concerned with memory usage and our tools. You might find that **grep**, when used as illustrated in our floppy analysis example, might not work as expected with larger images and could exit with an error similar to:

grep: memory exhausted

The most apparent cause for this is that **grep** does its searches line by line. When you are “grepping” a large disk image, you might find that you have a huge number of bytes to read through before **grep** comes across a newline character. What if **grep** had to read 200MB of data before coming across a newline? It would “exhaust” itself (the input buffer fills up).

What if we could force-feed **grep** some newlines? In our example analysis we are “grepping” for text. We are not concerned with non-text characters at all. If we could take the input stream to **grep** and change the non-text characters to newlines, **grep** would have no problem. Note that changing the input stream to **grep** does *not* change the image itself. Also, remember that we are still looking for a byte offset. Luckily, the character sizes remain the same, and so the offset does not change as we feed newlines into the stream (simply replacing one “character” with another).

Let’s say we want to take all of the control characters streaming into **grep** from the disk image and change them to newlines. We can use the *translate* command, **tr**, to accomplish this. Check out **man tr** for more information about this powerful command:

```
root@rock:~/evid # tr '[:cntrl:]' '\n' < image.disk | grep -abif list.txt > hits.txt
```

This command would read: “Translate all the characters contained in the set of *control characters ([:cntrl:])* to *newlines (\n)*. Take the input to **tr** from *image.disk* and pipe the output to **grep,** sending the results to *hits.txt*. This effectively changes the stream before it gets to **grep.**

This is only one of many possible problems you could come across. My point here is that when issues such as these arise, you need to be familiar enough with the tools Linux provides to be able to understand ***why*** such errors might have been produced, and how you can get around them. Remember, the shell tools and the GNU software that accompany a Linux distribution are extremely powerful, and are capable of tackling nearly any task. Where the standard shell fails, you might look at *perl* or *python* as options. These subjects are outside of the scope of the current presentation, but are introduced as fodder for further experimentation.

Preparing a Disk for the Suspect Image

One common practice in forensic disk analysis is to “wipe” a disk prior to restoring a forensic image to it. This ensures that any data found on the restored disk is *from* the image and not from “residual” data. That is, data left behind from a previous case or image.

We can use a special device as a source of zeros. This can be used to create empty files and wipe portions of disks. You can write zeros to an entire disk (or at least to those areas accessible to the kernel and user space) using the following command (assuming */dev/hdc* is the disk you want to wipe):

```
root@rock:~# dd if=/dev/zero of=/dev/hdc bs=4096
```

This starts at the beginning of the drive and writes zeros (the input file) to every sector on */dev/hdc* (the output file) in 4096 byte chunks (**bs** = "block size"). Specifying larger block sizes can speed the writing process. Experiment with different block sizes and see what effect it has on the writing speed (i.e. 32k, 64k, etc.). I've wiped 60GB disks in under an hour on a fast IDE controller with the proper drive parameters (see the next section for more info).

So how do we verify that our command to write zeros to a whole disk was a success? You could check random sectors with a hex editor, but that's not realistic for a large drive. One of the best methods would be to use the **xxd** command (command line hexdump) with the "autoskip" option (works if a drive is wiped with *0x00*). The output of this command on a zero'd drive would give just three lines. The first line, starting at offset zero with a row of zeros in the data area, followed by an asterisk (*) to indicate identical lines, and finally the last line, with the final offset followed by the remaining zeros in the data area. Here's and example of the command on a zero'd drive (floppy) and its output.

```
root@rock:~# xxd -a /dev/fd0
0000000: 0000 0000 0000 0000 0000 0000 0000 0000  ................
*
0167ff0: 0000 0000 0000 0000 0000 0000 0000 0000  ................
```

Obtaining Disk Information

Specific drive parameters can be displayed and set using the **hdparm** command (for IDE and SATA disks in recent versions). Check **hdparm's** man page for available options**.** For instance, setting DMA on a drive can dramatically speed things up. Note that while **hdparm** *may* be able to display settings on SATA disks, be aware that *setting* parameters is a different story. Drives must be capable of a given setting in order to work.

```
root@rock:~#  hdparm /dev/hda

/dev/hda:

 multcount    = 16 (on)
 IO_support   =  1 (32-bit)
 unmaskirq    =  0 (off)
 using_dma    =  0 (off)             <-- DMA is turned off
 keepsettings =  0 (off)
 readonly     =  0 (off)
 readahead    = 256 (on)
 geometry     = 65535/16/63, sectors = 60011642880, start = 0

root@rock:~# hdparm -d1 /dev/hda

/dev/hda:

 setting using_dma to 1 (on)        <-- We have turned DMA on with
 using_dma    =  1 (on)                 the -d1 option
```

In the above session, the first command displays the current parameters of the drive */dev/hda* and shows that DMA is off. The second command actually turns DMA on for that particular disk. Pay attention to the "multicount" and "IO_support" settings as well. Most modern distributions take care of this for you. Just be aware of the capability. Note that this is an IDE disk.

To obtain a more complete listing of a drive's information, you can use the **-I** switch with **hdparm**. Here is a sample of **hdparm** output on a SATA disk. Note that you are given the disk model, serial number and geometry information, to include user addressable sectors (output is edited for brevity):

```
root@rock:~#  hdparm -I /dev/sda

/dev/sda:

ATA device, with non-removable media
      Model Number:       ST3250823AS
      Serial Number:      3ND1M14Q
      Firmware Revision:  3.03
Standards:
      Used: ATA/ATAPI-6 T13 1410D revision 2
      Supported: 7 6 5 4 & some of 7
Configuration:
      Logical           max   current
      cylinders   16383 16383
      heads       16    16
      sectors/track     63    63
      --
      CHS current addressable sectors:   16514064
      LBA    user addressable sectors:  268435455
      LBA48  user addressable sectors:  488397168
Capabilities:
...
Commands/features:
      Enabled     Supported:
         *  SMART feature set
         *  Power Management feature set
         *  Write cache
...
         *  Host-initiated interface power management
         *  Phy event counters
         *  Software settings preservation
Checksum: correct
```

IX. Advanced (Beginner) Forensics

The following sections are more advanced and detailed. New tools are introduced to help round out some of your knowledge and provide a more solid footing on the capabilities of the Linux command line. The topics are still at the beginner level, but you should be at least somewhat comfortable with the command line before tackling the exercises. Although I've included the commands and much of the output for those who are reading this without the benefit of a Linux box nearby, it is important that you follow along on your own system as we go through the practical exercises. Typing at the keyboard and experimentation is the only way to learn.

The Command Line on Steroids

Let's dig a little deeper into the command line. Often there are arguments made about the usefulness of the command line interface (CLI) versus a GUI tool for analysis. I would argue that in the case of large sets of regimented data, the CLI can sometimes be faster and more flexible than many GUI tools available today.

As an example, we will look at a set of log files from a single Unix system. We are not going to analyze them for any sort of smoking gun. The point here is to illustrate the ability of commands through the CLI to organize and parse through data by using pipes to string a series of commands together, obtaining the desired output. Follow along with the example, and keep in mind that to get anywhere near proficient with this will require a great deal of reading and practice. The payoff is enormous.

Create a directory called "logs" and download the file *logs.v3.tar.gz* into that directory:

http://www.LinuxLEO.com/Files/logs.v3.tar.gz

A *.tar.gz* file is commonly referred to as a "tar archive". Much like a zip file in the Windows world. The *tar* part of the extension indicates that the file was created using the **tar** command (see **man tar** for more info). The *gz* extension indicates that the file was compressed (commonly with **gzip**). When you first download a tar archive, you should always have a look at the contents of the archive before decompressing, extracting and haphazardly writing the contents to your drive. View the contents of the archive with the following command:

```
root@rock:~/logs # tar tzvf logs.v3.tar.gz
-rw-r--r-- root/root      8282 2003-10-29 12:45 messages
-rw------- root/root      8302 2003-10-29 16:17 messages.1
-rw------- root/root      8293 2003-10-29 16:19 messages.2
-rw------- root/root      4694 2003-10-29 16:23 messages.3
-rw------- root/root      1215 2003-10-29 16:23 messages.4
```

The above **tar** command will list (**t**) and decompress (**z**) with verbose output (**v**) the file (**f**) *logs.v3.tar.gz*. We will use the **tar** command extensively throughout this document.

The archive contains 5 log files from a Unix system. The *messages* logs contain entries from a variety of sources, including the kernel and other applications. The numbered files result from log rotation. As the logs are filled, they are rotated and eventually deleted. On most Unix systems, the logs are found in */var/log/* or */var/adm*.

untar the file:

```
root@rock:~/logs # tar xzvf logs.v3.tar.gz
messages
messages.1
messages.2
messages.3
messages.4
```

This **tar** command differs little from our first command. Now, instead of listing the contents with the **t** option, we are extracting it with the **x** option. All the other options remain the same. Remember this for later use.

Let's have a look at one log entry. We pipe the output of **cat** to the command **head -n 1** so that we only get the 1st line:

```
root@rock:~/logs # cat messages | head -n 1
Nov 17 04:02:14 hostname123 syslogd 1.4.1: restart.
```

Each line in the log files begin with a date and time stamp. Next comes the hostname followed by the name of the application that generated the log message. Finally, the actual message is printed.

Let's assume these logs are from a victim system, and we want to analyze them and parse out the useful information. We are not going to worry about what we are actually seeing here, our object is to understand how to boil the information down to something useful.

First of all, rather than parsing each file individually, let's try and analyze all the logs at one time. They are all in the same format, and essentially they comprise one large log. We can use the **cat** command to add all the files together and send them to standard output. If we work on that data stream, then we are essentially making one large log out of all five logs. Can you see a potential problem with this?

```
root@rock:~/logs # cat messages* | less
Nov 17 04:02:14 hostname123 syslogd 1.4.1: restart.
Nov 17 04:05:46 hostname123 su(pam_unix)[19307]: session opened for user
news by (uid=0)
Nov 17 04:05:47 hostname123 su(pam_unix)[19307]: session closed for user
news
Nov 17 10:57:11 hostname123 sshd[32765]: Did not receive identification
string from 2xx.71.188.192
Nov 17 10:57:11 hostname123 sshd[32766]: Did not receive identification
string from 2xx.71.188.192
Nov 17 10:57:11 hostname123 sshd[32767]: Did not receive identification
string from 2xx.71.188.192
Nov 17 19:26:43 hostname123 sshd[2019]: Did not receive identification
string from 200.xx.72.129
Nov 18 04:06:04 hostname123 su(pam_unix)[5019]: session opened for user
news by
(uid=0)
Nov 18 04:06:05 hostname123 su(pam_unix)[5019]: session closed for user
news
Nov 18 18:55:06 hostname123 sshd[11204]: Did not receive identification
string from 6x.x2.248.243
Nov 19 04:05:42 hostname123 su(pam_unix)[15422]: session opened for user
news by (uid=0)
<continues>
```

If you look at the output (scroll using **less**), you will see that the dates ascend and then jump to an earlier date and then start to ascend again. This is because the later log entries are added to the *bottom* of each file, so as the files are added together, the dates appear to be out of order. What we really want to do is stream each file *backwards* so that they get added together with the most recent date in each file *at the top* instead of at the bottom. In this way, when the files are added together they are in order. In order to accomplish this, we use **tac** (yes, that's **cat** backwards).

```
root@rock:~/logs # tac messages* | less
Nov 23 18:27:00 hostname123 rc.sysinit: Mounting proc filesystem:
succeeded
Nov 23 18:27:58 hostname123 kernel:  hda: hda1 hda2 hda3 hda4 < hda5 hda6
hda7 >
Nov 23 18:27:58 hostname123 kernel: Partition check:
Nov 23 18:27:58 hostname123 kernel: ide-floppy driver 0.99.newide
Nov 23 18:27:58 hostname123 kernel: hda: 12594960 sectors (6449 MB) w/80KiB
Cache, CHS=784/
255/63, UDMA(33)
Nov 23 18:27:58 hostname123 kernel: blk: queue c035e6a4, I/O limit 4095Mb
(mask 0xffffffff)
Nov 23 18:27:58 hostname123 kernel: ide1 at 0x170-0x177,0x376 on irq 15
Nov 23 18:27:58 hostname123 kernel: ide0 at 0x1f0-0x1f7,0x3f6 on irq 14
Nov 23 18:27:58 hostname123 kernel: hdc: TOSHIBA CD-ROM XM-6202B, ATAPI CD/
DVD-ROM drive
Nov 23 18:27:58 hostname123 kernel: hda: QUANTUM FIREBALL SE6.4A, ATA DISK
drive
Nov 23 18:27:58 hostname123 kernel: ide1: BM-DMA at 0x14c8-0x14cf, BIOS
settings: hdc:D MA, hdd:pio
Nov 23 18:27:58 hostname123 kernel: ide0: BM-DMA at 0x14c0-0x14c7, BIOS
settings: hda:D MA, hdb:pio
Nov 23 18:27:58 hostname123 kernel: PIIX4: not 100%% native mode: will
probe irqs later
<continues>
```

Beautiful. The dates are now in order. We can now work on the stream of log entries as if they were one large (in order) file.

We will introduce a new command, **awk,** to help us view specific fields from the log entries, in this case, the dates. **awk** is an extremely powerful command. The version most often found on Linux systems is **gawk** (GNU **awk**). While we are going to use it as a stand-alone command, **awk** is actually a programming language on its own, and can be used to write scripts for organizing data. Our concentration will be centered on **awk's** "print" function. See **man awk** for more details.

Sets of repetitive data can often be divided into columns or "fields", depending on the structure of the file. In this case, the fields in the log files are separated by simple white space (**awk's** default field separator). The date is comprised of the first two fields (month and day).

```
root@rock:~/logs # tac messages* | awk '{print $1" "$2}' | less
Nov  23
Nov  23
Nov  23
Nov  23
Nov  23
<continues>
```

This command will stream all the log files (each one from bottom to top) and send the output to **awk** which will print the first field, *$1* (month), followed by a space (" "), followed by the second field, *$2* (day). This shows the month and day for every entry. Suppose I just want to see one of each date when an entry was made. I don't need to see repeating dates. I ask to see one of each unique line of output with **uniq**:

```
root@rock:~/logs # tac messages* | awk '{print $1" "$2}' | uniq | less
Feb 23
Nov 22
Nov 21
Nov 20
Nov 19
<continues>
```

This removes repeated dates, and shows me just those dates with log activity. If a particular date is of interest, I can **grep** the logs for that particular date:

```
root@rock:~/logs # tac messages* | grep "Nov  4"
Nov  4 17:41:27 hostname123 sshd[27630]: Received disconnect from
1xx.183.221.214: 11: Disconnect requested by Windows SSH Client.
Nov  4 17:13:07 hostname123 sshd(pam_unix)[27630]: session opened for
user root by (uid=0)
Nov  4 17:13:07 hostname123 sshd[27630]: Accepted password for root
from 1xx.183.221.214 port 1762 ssh2
Nov  4 17:08:23 hostname123 sshd(pam_unix)[27479]: session closed for
user root
Nov  4 17:07:11 hostname123 squid[27608]: Squid Parent: child process
27610 started
<continues>
```

(note there are ***2*** spaces between "Nov" and "4", one space will not work)

Of course, we have to keep in mind that this would give us any lines where the string "Nov 4" resided, not just in the date field. To be more explicit, we could say that we only want lines that *start* with "Nov 4", using the "^" (in our case, this gives essentially the same output):

```
root@rock:~/logs # tac messages* | grep ^"Nov  4"
Nov  4 17:41:27 hostname123 sshd[27630]: Received disconnect from
1xx.183.221.214: 11: Disconnect requested by Windows SSH Client.
Nov  4 17:13:07 hostname123 sshd(pam_unix)[27630]: session opened for
user root by (uid=0)
<continues>
```

Also, if we don't *know* that there are *two* spaces between "Nov" and "4", we can tell **grep** to look for any number of spaces between the two:

```
root@rock:~/logs # tac messages* | grep ^"Nov[ ]*4"
Nov  4 17:41:27 hostname123 sshd[27630]: Received disconnect from
1xx.183.221.214: 11: Disconnect requested by Windows SSH Client.
Nov  4 17:13:07 hostname123 sshd(pam_unix)[27630]: session opened for
user root by (uid=0)
Nov  4 17:13:07 hostname123 sshd[27630]: Accepted password for root
from 1xx.183.221.214 port 1762 ssh2
Nov  4 17:08:23 hostname123 sshd(pam_unix)[27479]: session closed for
user root
Nov  4 17:07:11 hostname123 squid[27608]: Squid Parent: child process
27610 started
<continues>
```

The above **grep** expression translates to "Lines starting (^) with the string "Nov" followed by zero or more (*) of the preceding characters ([/space/]) followed by a 4". Obviously, this is a complex issue. Knowing how to use regular expression will give you huge flexibility in sorting through and organizing large sets of data. As mentioned earlier, read the **grep** man page for a good primer on regular expressions.

As we look through the log files, we may come across entries that appear suspect. Perhaps we need to gather all the entries that we see containing the string "Did not receive identification string from <*IP*>" for further analysis.

```
root@rock:~/logs # tac messages* | grep "identification string" | less
Nov 22 23:48:47 hostname123 sshd[19380]: Did not receive
identification string from 19x.xx9.220.35
Nov 22 23:48:47 hostname123 sshd[19379]: Did not receive
identification string from 19x.xx9.220.35
Nov 20 14:13:11 hostname123 sshd[29854]: Did not receive
identification string from 200.xx.114.131
Nov 18 18:55:06 hostname123 sshd[11204]: Did not receive
identification string from 6x.x2.248.243
<continues>
```

Now we just want the date (fields 1 and 2), the time (field 3) and the remote IP address that generated the log entry. The IP address is the last field. Rather than count each word in the entry to get to the field number of the IP, we can simply use the variable "$NF", which means "number of fields". Since the IP is the last field, its field number is equal to the number of fields:

```
root@rock:~/logs # tac messages* | grep "identification string" |
                   awk '{print $1" "$2" "$3" "$NF}' | less
Nov 22 23:48:47 19x.xx9.220.35
Nov 22 23:48:47 19x.xx9.220.35
Nov 20 14:13:11 200.xx.114.131
Nov 18 18:55:06 6x.x2.248.243
Nov 17 19:26:43 200.xx.72.129
<continues>
```

Note that when the command is too long for one line, it will automatically wrap to the next line.

We can add some tabs (**"\t"**) in place of spaces in our output to make it more readable:

```
root@rock:~/logs # tac messages* | grep "identification string" |
                   awk '{print $1" "$2"\t"$3"\t"$NF}' | less
Nov 22  23:48:47        19x.xx9.220.35
Nov 22  23:48:47        19x.xx9.220.35
Nov 20  14:13:11        200.xx.114.131
Nov 18  18:55:06        6x.x2.248.243
Nov 17  19:26:43        200.xx.72.129
<continues>
```

This can all be redirected to an analysis log or text file for easy addition to a report (note that "> **report.txt**" *creates* the report file, ">> **report.txt**" *appends* to it). The following commands are typed on one line each:

```
root@rock:~/logs # echo "Localhost123: Log entries from /var/log/messages" > report.txt
root@rock:~/logs # echo "\"Did not receive identification string\":" >> report.txt
root@rock:~/logs # tac messages* | grep "identification string" |
                   awk '{print $1" "$2"\t"$3"\t"$NF}' >> report.txt
```

We can also get a sorted (**sort**) list of the unique (**-u**) IP addresses involved in the same way:

```
root@rock:~/logs # echo "Unique IP addresses:" >> report.txt
root@rock:~/logs # tac messages* | grep "identification string" | awk '{print $NF}' |
                   sort -u >> report.txt
```

The second command above prints only the last field (**$NF**) of our **grep** output (which is the IP address). The resulting list of IP addresses can also be fed to a script that does **nslookup** or **whois** database queries.

You can view the resulting report (*report.txt*) using the **less** command.

As with all the exercises in this document, we have just sampled the abilities of the Linux command line. It all seems somewhat convoluted to the beginner. After some practice and experience with different sets of data, you will find that you can glance at a file and say “I want that information”, and be able to write a quick piped command to get what you want in a readable format *in a matter of seconds*. As with all language skills, the Linux command line “language” is perishable. Keep a good reference handy and remember that you might have to look up syntax a few times before it becomes second nature.

Fun with DD

We've already done some simple imaging and wiping using **dd**, let's explore some other uses for this flexible tool. **dd** is sort of like a little forensic Swiss army knife (talk about over-used clichés!). It has lots of applications, limited only by your imagination.

Splitting Files and Images

One function we might find useful would be the ability to split images up into usable chunks, either for archiving or for use in another program. We will first discuss using **split** on its own, then in conjunction with **dd** for "on the fly" splitting.

For example, you might have a 10GB image that you want to split into 640MB parts so they can be written to CD-R media. Or, if you use forensic software in Windows and need files no larger than 2GB (for a FAT32 partition), you might want to split the image into 2GB pieces. For this we use the **split** command.

split normally works on lines of input (i.e. from a text file). But if we use the **–b** option, we force split to treat the file as *binary* input and lines are ignored. We can specify the size of the files we want along with the prefix we want for the output files. In newer versions of **split** we can also use the **-d** option to give us numerical numbering (**.01, *.02, *.03*, etc.) for the output files as opposed to alphabetical (**.aa, *.ab, *.ac*, etc.). The command looks like:

split -d -b XXm <file to be split> <prefix of output files>

where **XX** is the size of the resulting files. For example, if we have a 6GB image called *image.disk1.dd*, we can split it into 2GB files using the following command:

```
root@rock:~# split -d -b 2000m image.disk1.dd image.split.
```

This would result in 3 files (2GB in size) each named with the prefix "image.split." as specified in the command, followed by "01", "02", "03", and so on (assuming a newer version of **split** that supports the **-d** option is used):

```
root@rock:~# ls image.split.*
image.split.01  image.split.02  image.split.03
```

The process can be reversed. If we want to reassemble the image from the split parts (from CD-R, etc.), we can use the **cat** command and redirect the output to a new file. Remember **cat** simply streams the specified files to standard output. If you redirect this output, the files are assembled into one.

```
root@rock:~# cat image.split.01 image.split.02 image.split.03 > image.new
```

Or

```
root@rock:~# cat image.split.0* > image.new
```

Another way of accomplishing this would be to split the image as we create it (i.e. from a **dd** command). This is essentially the "on the fly" splitting we mentioned earlier. We do this by piping the output of the **dd** command straight to **split**. Assuming our subject drive is */dev/hdc*, we would use the command:

```
root@rock:~# dd if=/dev/hdc | split -d -b 2000m – image.split.
```

In this case, instead of giving the name of the file to be split in the **split** command, we give a simple "**-**" (after the "2000m"). The single dash is a descriptor that means "standard input". In other words, the command is taking its input from the data pipe provided by the standard output of **dd** instead of from a file.

Once we have the image, the same technique using **cat** will allow us to reassemble it for hashing or analysis.

For practice, let's take the practical exercise floppy disk we used earlier and try this method on that disk, splitting it into 360k pieces. If you don't have a floppy disk, just use a USB thumb drive and replace */dev/fd0* in the following command with */dev/sdx* (where *x* is your thumb drive). Obtain a hash first, so that we can compare the split files and the original and make sure that the splitting changes nothing:

```
root@rock:~# sha1sum /dev/fd0
f5ee9cf56f23e5f5773e2a4854360404a62015cf /dev/fd0
root@rock:~# dd if=practical.floppy.dd | split -d -b 360k - floppy.split.
2880+0 records in
2880+0 records out
```

– remember, the “records” are 512 byte blocks (times 2880 = 1.44Mb)

```
root@rock:~# ls -lh
total 2.9M
-rw-r--r--  1 root root 360K Jan 31 12:56 floppy.split.01
-rw-r--r--  1 root root 360K Jan 31 12:56 floppy.split.02
-rw-r--r--  1 root root 360K Jan 31 12:56 floppy.split.03
-rw-r--r--  1 root root 360K Jan 31 12:56 floppy.split.04

root@rock:~# cat floppy.split.0* | sha1sum
f5ee9cf56f23e5f5773e2a4854360404a62015cf  -
```

(The out put of the second command above shows a “-“ in place of the filename. This represents the fact that the hash was calculated from “standard input” to sha1sum [from the pipe], not a file or device)

```
root@rock:~# cat floppy.split.0* > new.floppy.image

root@rock:~# ls -lh
total 4.3M
-rw-r--r--  1 root root 360K Jan 31 12:56 floppy.split.01
-rw-r--r--  1 root root 360K Jan 31 12:56 floppy.split.02
-rw-r--r--  1 root root 360K Jan 31 12:56 floppy.split.03
-rw-r--r--  1 root root 360K Jan 31 12:56 floppy.split.04
-rw-r--r--  1 root root 1.5M Jan 31 13:01 new.floppy.image

root@rock:~# sha1sum new.floppy.image
f5ee9cf56f23e5f5773e2a4854360404a62015cf  new.floppy.image
```

Above, we reassemble the floppy image using **cat**, and then see the new image in a directory listing. We then hash the reassembled image using **sha1sum**.

Looking at the output of the above commands, we see that all the sha1sum’s match (don't confuse **sha1sum** output with **md5sum** output)**.** We find the same hash for the disk, for the split images “cat-ed” together, and for the newly reassembled image.

Compression on the Fly with DD

Another useful capability while imaging is compression. Considering our concern for forensic application here, we will be sure to manage our compression technique so that we can verify our hashes without having to decompress and write our images out before checking them.

For this exercise, we'll use the GNU **gzip** application. **gzip** is a command line utility that allows us some fairly granular control over the compression process.

First, for the sake of familiarity, let's look at the simple use of **gzip** on a single file and explore some of the options at our disposal. I have created a directory called *testcomp* and I've copied the image file *practical.floppy.dd* into that directory to practice on. This gives me an uncluttered place to experiment. First, let's double check the hash of the floppy image:

```
root@rock:~/testcomp# ls -lh
total 1.5M
-rw-r--r-- 1 root root 1.5M May 22 09:11 practical.floppy.dd

root@rock:~/testcomp# sha1sum practical.floppy.dd
f5ee9cf56f23e5f5773e2a4854360404a62015cf  practical.floppy.dd
```

Now, in its most simple form, we can call **gzip** and simply provide the name of the file we want compressed. This will *replace* the original file with a compressed file that has a *.gz* suffix appended.

```
root@rock:~/testcomp # gzip practical.floppy.dd

root@rock:~/testcomp # ls -lh
total 636K
-rw-r--r-- 1 root root 632K May 22 09:11 practical.floppy.dd.gz
```

So now we see that we have replaced our original 1.5M file with a 632K file that has a *.gz* extension. To decompress the resulting *.gz* file:

```
root@rock:~/testcomp # gzip -d practical.floppy.dd.gz

root@rock:~/testcomp # ls -lh
total 1.5M
-rw-r--r-- 1 root root 1.5M May 22 09:11 practical.floppy.dd
root@rock:~/testcomp# sha1sum practical.floppy.dd
f5ee9cf56f23e5f5773e2a4854360404a62015cf  practical.floppy.dd
```

We've decompressed the file and replaced the *.gz* file with the original image. A check of the hash shows that all is in order.

Suppose we would like to compress a file but leave the original intact. We can use the **gzip** command with the **-c** option. This writes to standard output instead of a replacement file. When using this option we need to redirect the output to a filename of our choosing so that the compressed file is not simply streamed to our terminal. Here is a sample session using this technique:

```
root@rock:~/testcomp # ls -lh
total 1.5M
-rw-r--r-- 1 root root 1.5M May 22 09:11 practical.floppy.dd

root@rock:~/testcomp # sha1sum practical.floppy.dd
f5ee9cf56f23e5f5773e2a4854360404a62015cf  practical.floppy.dd

root@rock:~/testcomp # gzip -c practical.floppy.dd > floppy.dd.gz

root@rock:~/testcomp # ls -lh
total 2.1M
-rw-r--r-- 1 root root 632K May 22 09:38 floppy.dd.gz
-rw-r--r-- 1 root root 1.5M May 22 09:11 practical.floppy.dd

root@rock:~/testcomp # gzip -cd floppy.dd.gz > floppy.dd
root@rock:~/testcomp # ls -lh
total 3.5M
-rw-r--r-- 1 root root 1.5M May 22 09:40 floppy.dd
-rw-r--r-- 1 root root 632K May 22 09:38 floppy.dd.gz
-rw-r--r-- 1 root root 1.5M May 22 09:39 practical.floppy.dd

root@rock:~/testcomp # sha1sum practical.floppy.dd
f5ee9cf56f23e5f5773e2a4854360404a62015cf  practical.floppy.dd
```

In the above output, we see that the first directory listing shows the single image file. We check the hash and then compress using **gzip -c** which writes to standard output. We redirect that output to a new file (name of our choice). The second listing shows that the original file remains, and the compressed file is created. We then use **gzip -cd** to decompress the file, redirecting the output to a new file and this time preserving the compressed file.

These are very basic options for the use of **gzip.** The reason we learn the **-c** option is to allow us to decompress a file and pipe the output to a hash algorithm. In a more practical sense, this allows us to create a compressed image and check the hash of that image without writing the file twice.

If we go back to a single image file in our directory, we can see this in action. Remove all the files we just created (using the **rm** command) and leave the single original **dd** image. Now we will create a single compressed file from that original image and then check the hash of the *compressed* file to ensure it's validity:

```
root@rock:~/testcomp # ls -lh
total 1.5M
-rw-r--r-- 1 root root 1.5M May 22 09:11 practical.floppy.dd

root@rock:~/testcomp # sha1sum practical.floppy.dd
f5ee9cf56f23e5f5773e2a4854360404a62015cf  practical.floppy.dd

root@rock:~/testcomp # gzip practical.floppy.dd


root@rock:~/testcomp # ls -lh
total 636K
-rw-r--r-- 1 root root 632K May 22 09:52 practical floppy.dd.gz


root@rock:~/testcomp #gzip -cd practical.floppy.dd.gz | sha1sum
f5ee9cf56f23e5f5773e2a4854360404a62015cf  -


root@rock:~/testcomp # ls -lh
total 636K
-rw-r--r-- 1 root root 632K May 22 09:52 practical floppy.dd.gz
```

First we see that we have the correct hash. Then we compress the image with a simple **gzip** command that replaces the original file. Now, all we want to do next is check the hash of our compressed image without having to write out a new image. We do this by using **gzip -c** (to standard out) **-d** (decompress), passing the name of our compressed file but piping the output to our hash algorithm (in this case **sha1sum**). The result shows the correct hash of the output stream, where the output stream is signified by the "**-**".

Okay, so now that we have a basic grasp of using **gzip** to compress, decompress, and verify hashes, let's put it to work "on the fly" using **dd** to create a compressed image. We will then check the compressed image's hash value against an original hash.

Let's continue to use our practical exercise floppy image. First, write the image back to a physical floppy disk (as we did in the original practical exercise). Clear out the *testcomp* directory so that we have a clean place to write our image to.

Obtaining a compressed **dd** image on the fly is simply a matter of streaming our **dd** output through a pipe to the **gzip** command and redirecting *that* output to a file. Our resulting image's hash can then be checked using the same method we used above. Consider the following session. Our physical device is the floppy disk in */dev/fd0*.

```
root@rock:~/testcomp # ls -lh
<empty directory>
root@rock:~/testcomp # sha1sum /dev/fd0
f5ee9cf56f23e5f5773e2a4854360404a62015cf  /dev/fd0

root@rock:~/testcomp # dd if=/dev/fd0 | gzip -c > floppy.dd.gz
2880+0 records in
2880+0 records out
1474560 bytes (1.5 MB) copied, 0.393626 s, 3.7 MB/s

root@rock:~/testcomp # ls -lh
total 636K
-rw-r--r-- 1 root root 632K May 22 09:58 floppy.dd.gz

root@rock:~/testcomp # gzip -cd floppy.dd.gz | sha1sum
f5ee9cf56f23e5f5773e2a4854360404a62015cf  -

root@rock:~/testcomp # ls -lh
total 636K
-rw-r--r-- 1 root root 632K May 22 09:58 floppy.dd.gz
```

In the above **dd** command there is no “output file” specified (no **“of=”**). The output is simply directed straight to **gzip** for redirection into a new file. We then follow up with our integrity check by decompressing the file to standard output and hashing the stream. The hashes match, so we can see that we used **dd** to acquire a compressed image, and verified our acquisition without the need to decompress (and write to disk) first.

Data Carving with DD

In this next example, we will use **dd** to carve a JPEG image from a chunk of raw data. By itself, this is not a real useful exercise. There are lots of tools out there that will “carve” files from forensic images, including a simple cut and paste from a hex editor. However, the purpose of this exercise is to help you become more familiar with **dd**. In addition, you will get a chance to use a number of other tools in preparation for the “carving”. This will help familiarize you further with the Linux toolbox. First you will need to download the raw data chunk from:

http://www.LinuxLEO.com/Files/image_carve.raw

Have a brief look at the file *image_carve.raw* with your wonderful command line hexdump tool, **xxd**:

```
root@rock:~# xxd image_carve.raw | less
0000000: 776a 176b 5fd3 9eae 247f 33b3 efbe 8d6a  wj.k_...$.3....j
0000010: d3a9 daa0 8eef c199 102f 7eaa 0c68 a908  ........./~..h..
0000020: fca4 7e13 dc6b 17a9 e973 35a0 cfc3 9360  ..~..k...s5....`
0000030: f9c0 a6b9 1476 b268 de0f 94fa a2f4 4705  .....v.h......G.
0000040: 452d 7691 eb4f 2fa7 b31f 328b c07a ce3d  E-v..O/...2..z.=
<continues>
```

It’s really just a file full of random characters. Somewhere inside there is a standard JPEG image. Let’s go through the steps we need to take to “recover” the picture file using **dd** and other Linux tools. We are going to stick with command line tools available in most default installations.

First we need a plan. How would we go about recovering the file? What are the things we need to know to get the image (picture) out, and only the image? Imagine **dd** as a pair of scissors. We need to know where to put the scissors to start cutting, and we need to know where to stop cutting. Finding the start of the JPEG and the end of the JPEG can tell us this. Once we know where we will start and stop, we can calculate the *size* of the JPEG. We can then tell **dd** where to start cutting, and how much to cut. The output file will be our JPEG image. Easy, right? So here’s our plan, and the tools we’ll use:

1) Find the start of the JPEG (**xxd** and **grep**)
2) Find the end of the JPEG (**xxd** and **grep**)
3) Calculate the size of the JPEG (in bytes using **bc**)
4) Cut from the start to the end and output to a file (using **dd**)

This exercise starts with the assumption that we are familiar with standard file headers. Since we will be searching for a standard JPEG image within the data chunk, we will start with the stipulation that the JPEG header begins with hex *ffd8* with a six-byte offset to the string "*JFIF*". The end of the standard JPEG is marked by hex *ffd9*.

Let's go ahead with step 1: Using **xxd**, we pipe the output of our *image_carve.raw* file to grep and look for the start of the JPEG[9]:

```
root@rock:~# xxd image_carve.raw | grep ffd8
00052a0: b4f1 559c ffd8 ffe0 0010 4a46 4946 0001  ..U.......JFIF..
```

As the output shows, using **grep** we've found the pattern "*ffd8*" near the string "*JFIF*". The start of a standard JPEG file header has been found. The offset (in hex) for the *beginning of this line of* ***xxd*** *output* is *00052a0.* Now we can calculate the byte offset in decimal. For this we will use the **bc** command. **bc** is a command line "calculator", useful for conversions and calculations. It can be used either interactively or take piped input. In this case we will echo the hex offset to **bc**, first telling it that the value is in base 16. **bc** will return the decimal value.

```
root@rock:~# echo "ibase=16;00052A0" | bc
21152
```

It's important that you use *uppercase letters* in the hex value. Note that this is NOT the start of the JPEG, just the start of the line in **xxd's** output. The "*ffd8*" string is actually located another 4 bytes farther into that line of output. So we add 4 to the start of the line. Our offset is now *21156*. We have found and calculated the start of the JPEG image in our data chunk.

Now it's time to find the end of the file.

Since we already know where the JPEG starts, we will start our search for the end of the file *from that point.* Again using **xxd** and **grep** we search for the string:

```
root@rock:~# xxd -s 21156 image_carve.raw | grep ffd9
0006c74: ffd9 d175 650b ce68 4543 0bf5 6705 a73c  ...ue..hEC..g..<
```

[9] The perceptive among you will notice that this is a "perfect world" situation. There are a number of variables that can make this operation more difficult. The **grep** command can be adjusted for many situations using a complex regular expression (outside the scope of this document).

The **–s 21156** specifies where to start searching (since we know this is the front of the JPEG, there's no reason to search before it and we eliminate false hits from that region). The output shows the first "*ffd9*" at hex offset *0006c74*. Let's convert that to decimal:

```
root@rock:~# echo "ibase=16;0006C74" | bc
27764
```

Because that is the offset for the *start* of the line, we need to add 2 to the value to include the ffd9 (giving us *27766*). Now that we know the start and the end of the file, we can calculate the size:

```
root@rock:~# echo "27766 - 21156" | bc
6610
```

We now know the file is 6610 bytes in size, and it starts at byte offset 21156. The carving is the easy part! We will use **dd** with three options:

skip= how far into the data chuck we begin "cutting".
bs= **(block size)** the number of bytes we include as a "block".
count = the number of blocks we will be "cutting".

The input file for the **dd** command is *image_carve.raw*. Obviously, the value of **skip** will be the offset to the start of the JPEG. The easiest way to handle the block size is to specify it as **bs=1** (meaning one byte) and then setting **count** to the size of the file. The name of the output file is arbitrary.

```
root@rock:~# dd if=image_carve.raw of=carv.jpg skip=21156 bs=1 count=6610
6610+0 records in
6610+0 records out
```

You should now have a file in your current directory called *carv.jpg*. If you are in X, simply use the **xv** command to view the file (or any other image viewer) and see what you've got.

```
root@rock:~# xv carv.jpg
```

xv from a command line (while in an X session) will display the graphic image in it's own window.

Carving Partitions with DD

Now we can try another useful exercise in carving with **dd**. Often, you will obtain or be given a **dd** image of a full disk. At times you might find it desirable to have each separate partition within the disk available to search or mount. Remember, you cannot simply mount an entire disk image, only the partitions.

There are commercial solutions to mounting partitions within an entire image, like SMART for Linux forensic software. Recent advances in forensic tools like The Sleuthkit have make the ability to carve partitions from an image less important that it once was. For the beginning Linux forensics student, I would still consider this an important skill, however. Plus, it's just good practice for a number of Linux commands. We introduce this technique here not to teach it for practical use, but to provide another practical exercise using a number of important command line tools.

The method we will use in this exercise entails identifying the partitions within a **dd** image with **fdisk** or **sfdisk.** We will then use **dd** to carve the partitions out of the image.

First, let's grab the practice disk image that we will be working on. This is a **dd** image of a 330MB disk from a Linux system that was compromised.

http://www.LinuxLEO.com/Files/able2.tar.gz

The **tar** archive contains the disk image, the MD5 digest values, and the imaging log file with information collected during the imaging process.

Create a directory called "*able2*" in your */root* directory. This will be the working directory for the following exercise. Again, the vast majority of steps taken in preparation for, and execution of a forensic analysis require root access to commands and devices. Once you have downloaded the file into that *able2* directory, change to that directory and check the md5sum[10] (it should match the output below):

```
root@rock:~/able2 # md5sum able2.tar.gz
7863920262cad3b30333192fd50965b8  able2.tar.gz
```

The file name is derived from the original hostname of the machine that was compromised. Very often we name our cases and evidence with the

[10] Yes, we are using **md5sum** here but we used **sha1sum** earlier...Consistency is overrated! ;-)

original hostname of the machine we are investigating (whether a victim or a hostile).

If the MD5 matches, then we can continue…We now need to check the contents of the **tar** archive, then extract and decompress the archive.

```
root@rock:~/able2 # tar tzvf able2.tar.gz
-rwxrwxr-x root/root 345830400 2003-08-10 21:16:36 able2.dd   <-Disk image
-rwxrwxr-x root/root      3700 2003-08-11 07:56:04 able2.log  <-collection log
-rwxrwxr-x root/root        43 2003-08-10 21:16:36 md5.dd     <-image hash
-rwxrwxr-x root/root        43 2003-08-10 21:04:40 md5.hdd    <-original disk hash
root@rock:~/able2 # tar xzvf able2.tar.gz
able2.dd
able2.log
md5.dd
md5.hdd
```

The second command above executes the **tar** command with the options **x** to extract the files, **z** to decompress the files, **v** for verbose output, and **f** to specify the file.

Have a look at the files that result:

```
root@rock:~/able2 # ls -lh
total 465M
-rwxrwxr-x  1 root root 330M Aug 10  2003 able2.dd
-rwxrwxr-x  1 root root 3.7K Aug 11  2003 able2.log
-rwxr-x---  1 root root 135M Jan 31 13:18 able2.tar.gz
-rwxrwxr-x  1 root root   43 Aug 10  2003 md5.dd
-rwxrwxr-x  1 root root   43 Aug 10  2003 md5.hdd
```

The output of **ls –lh** (the **–lh** is for "long list with human readable sizes") shows the 330MB **dd** image, the log file and two files that record the original MD5 hashes, one for the image (*md5.dd*) and one for the original disk (*md5.hdd*). At this point you can check the hash of the *able2.dd* and compare it to the value stored in *md5.dd* (gathered when the system was originally imaged) to be sure the image is intact.

```
root@rock:~/able2 # cat md5.dd
02b2d6fc742895fa4af9fa566240b880  able2.dd

root@rock:~/able2 # md5sum able2.dd
02b2d6fc742895fa4af9fa566240b880  able2.dd
```

Okay, now we have our image, and we have verified that it is an accurate copy. We now want to know a little bit about the contents of the image and what it represents. During the evidence acquisition process, it is essential that information about the disk be recorded. Standard operating procedures should include collection of disk and system information, and not just the **dd** image itself.

The file *able2.log* was created from the output of various commands used **during the evidence collection process**. The log includes information about the investigator that gathered the evidence, information about the system, and the output of commands including **hdparm**, **fdisk**, **sfdisk** and hashing functions. We create the log file by appending (">>") the output of the commands, in sequence, to the log:

command **>> logfile.txt**

Look at the log file, *able2.log,* using **less** and scroll down to the section that shows the structure of the disk (the output of **fdisk –l /dev/hdd** and **sfdisk –l –uS /dev/hdd**):

```
root@rock:~/able2 # less able2.log
<scrolled output>
#################################################################
fdisk output for SUBJECT disk:

Disk /dev/hdd: 345 MB, 345830400 bytes
15 heads, 57 sectors/track, 790 cylinders
Units = cylinders of 855 * 512 = 437760 bytes

   Device Boot      Start         End      Blocks   Id  System
/dev/hdd1               1          12        5101+  83  Linux
/dev/hdd2              13         132       51300   83  Linux
/dev/hdd3             133         209       32917+  82  Linux swap
/dev/hdd4             210         790      248377+  83  Linux

#################################################################
sfdisk output for SUBJECT disk:

Disk /dev/hdd: 790 cylinders, 15 heads, 57 sectors/track
Units = sectors of 512 bytes, counting from 0

   Device Boot    Start       End   #sectors  Id  System
/dev/hdd1            57     10259      10203  83  Linux
/dev/hdd2         10260    112859     102600  83  Linux
/dev/hdd3        112860    178694      65835  82  Linux swap
/dev/hdd4        178695    675449     496755  83  Linux

#################################################################
```

The output shown above is directly from the victim hard drive (the machine *able2*), recorded prior to obtaining the **dd** image. It shows that there are 4 partitions on the drive. The data partitions are *hdd1, hdd2* and *hdd4*. The *hdd3* partition is actually a *swap* partition (for virtual memory). Remember that the designation *hdd* indicates that the victim hard drive was attached to our forensic workstation as the slave drive on the secondary IDE controller during the imaging process, NOT how it was attached in the original machine.

The command **sfdisk –l –uS /dev/hdd** gave us the second listing above and shows the partition sizes in units of "sectors" (**-uS)**. The output also gives us the start of the partition. For our partition carving exercise (as with the raw data carving), all we need is the starting offset, and the size.

Let's go ahead and **dd** out each partition. If you have the output of **sfdisk –l –uS /dev/hdx,** the job is easy.

```
root@rock:~/able2 # dd if=able2.dd of=able2.part1.dd bs=512 skip=57 count=10203
10203+0 records in
10203+0 records out
root@rock:~/able2 # dd if=able2.dd of=able2.part2.dd bs=512 skip=10260 count=102600
102600+0 records in
102600+0 records out
root@rock:~/able2 # dd if=able2.dd of=able2.part3.dd bs=512 skip=112860 count=65835
65835+0 records in
65835+0 records out
root@rock:~/able2 # dd if=able2.dd of=able2.part4.dd bs=512 skip=178695 count=496755
496755+0 records in
496755+0 records out
```

Examine these commands closely. The input file (**if=able2.dd**) is the full disk image. The output files (**of=able2.part#.dd**) will contain each of the partitions. The block size that we are using is the sector size (**bs=512)**, which matches the output of the **sfdisk** command. Each **dd** section needs to start where each partition begins (**skip=X),** and cut as far as the partition goes (**count=Y).** We also obtained partition number three, the swap partition. This can also be searched with **grep** and **strings** (or carving utilities) for evidence.

This will leave you with four *able2.part*.dd* files in your current directory that can now be loop mounted.

What if you have a **dd** image of the full disk, but no log file or access to the original disk, and therefore no info from **sfdisk** or **fdisk**? We can run the **sfdisk** or **fdisk** commands directly on the image if we like. Remember that the original disk that the image was obtained from was seen as a simple file (*/dev/hdx*) and the image we obtain using **dd** is also simply a file. So why would tools like **fdisk** treat them any differently. The hashes match, so they are essentially the same file:

```
root@rock:~/able2 # sfdisk -l -uS able2.dd
Disk able2.dd: cannot get geometry
...<error messages>
Units = sectors of 512 bytes, counting from 0

   Device Boot    Start       End   #sectors  Id  System
able2.dd1            57     10259      10203  83  Linux
able2.dd2         10260    112859     102600  83  Linux
able2.dd3        112860    178694      65835  82  Linux swap / Solaris
able2.dd4        178695    675449     496755  83  Linux
```

Aside from the error messages at the beginning of the output (removed for readability), notice that the actual disk geometry (in sectors) matches that taken from the original disk. The partitions are now noted as *able2.dd**, indicating, *"able2.dd* image, partitions 1 through 4". In a pinch, we could use this to gather information from the image file we were given, to determine the partitioning scheme of the disk that was imaged.

Unfortunately, you cannot mount the partitions associated with *able2.dd**. The block devices don't actually exist *(able2.dd*).*

Determining the Subject Disk File System Structure

Going back to our *able2* case **dd** images, we now have the original image along with the partition images that we carved out.

able2.dd	(original image)
able2.part1.dd	(1st Partition)
able2.part2.dd	(2nd Partition)
able2.part3.dd	(3rd Partition)
able2.part4.dd	(4th Partition)

The next trick is to mount the partitions in such a way that we reconstruct the original file system. This generally pertains to subject disks that were imaged from Unix hosts.

One of the benefits of Linux/Unix systems is the ability to separate the file system across partitions. This can be done for any number of reasons, allowing for flexibility where there are concerns about disk space or security, etc.

For example, a System Administrator may decide to keep the directory */var/log* on its own separate partition. This might be done in an attempt to prevent rampant log files from filling the root ("/" not "*/root*") partition and bringing the system down. It is common to see */boot* in its own partition as well. This allows the kernel image to be placed near "the front" (in terms of cylinders) of a hard drive, an issue in older versions of the Linux boot loader LILO. There are also a variety of security implications addressed by this setup.

So when you have a disk with multiple partitions, how do you find out the structure of the file system? Earlier in this paper we discussed the */etc/fstab* file. This file maintains the mounting information for each file system, including the physical partition; mount point, file system type, and options. Once we find this file, reconstructing the system is easy. With experience, you will start to get a feel for how partitions are setup, and where to look for the *fstab*. To make things simple here, just mount each partition (loopback, read only) and have a look around.

One thing we might like to know is what sort of file system is on each partition before we try and mount them. We can use the **file** command to do this[11]. Remember from our earlier exercise that the **file** command determines the type of file by looking for "header" information.

```
root@rock:~/able2 # file able2.part*
able2.part1.dd: Linux rev 1.0 ext2 filesystem data (mounted or unclean)
able2.part2.dd: Linux rev 1.0 ext2 filesystem data (mounted or unclean)
able2.part3.dd: Linux/i386 swap file (new style) 1 (4K pages) size 8228 pages
able2.part4.dd: Linux rev 1.0 ext2 filesystem data (mounted or unclean)
```

Previously, we were able to determine that the partitions were "Linux" partitions from the output of **fdisk** and **sfdisk.** Now **file** informs us that the file system type is *ext2*[12]. We can use this information to mount the partitions.

```
root@rock:~/able2 # mount -t ext2 -o ro,loop able2.part1.dd /mnt/analysis/
```

Do this for each partition (either unmounting between partitions, or mounting to a different mount point) and you will eventually find the */etc* directory containing the *fstab* file in *able2.part2.dd* with the following important entries:

```
root@rock:~/able2 # cat /mnt/analysis/etc/fstab
/dev/hda2        /                   ext2    defaults        1 1
/dev/hda1        /boot               ext2    defaults        1 2
/dev/hda4        /usr                ext2    defaults        1 2
/dev/hda3        swap                swap    defaults        0 0
```

[11] Keep in mind that the **file** command relies on the contents of the *magic* file to determine a file type. If this command does not work for you in the following example, then it is most likely because the magic file on your system does not include headers for file system types.

[12] You can also use the *auto* file system type under the mount command, but I prefer to be explicit. Check **man mount** for more information.

So now we see that the logical file system was constructed from three separate partitions (note that */dev/hda* here refers to the disk when it is mounted in the original system):

```
"/" (root)        mounted from /dev/hda2 (data on hda2)
     |_ bin/            (data on hda2)
     |_boot/      mounted from /dev/hda1 (data on hda1)
     |_dev/             (data on hda2)
     |_etc/             (data on hda2)
     |_home/            (data on hda2)
     |_lib/             (data on hda2)
     |_opt/             (data on hda2)
     |_proc/            (data on hda2)
     |_usr/       mounted from/dev/hda4 (data on hda4)
     |_root/            (data on hda2)
     |_sbin/            (data on hda2)
     |_tmp/             (data on hda2)
     |_var/             (data on hda2)
```

Now we can create the original file system at our analysis mount point. The mount point */mnt/analysis* already exists. When you mount the root partition of *able2.dd* on */mnt/analysis*, you will note that the directories */mnt/analysis/boot* and */mnt/analysis/usr* are empty. That is because we have to mount those partitions to access the contents of those directories.

```
root@rock:~/able2 # mount -t ext2 -o ro,loop able2.part2.dd /mnt/analysis/
root@rock:~/able2 # mount -t ext2 -o ro,loop able2.part1.dd /mnt/analysis/boot
root@rock:~/able2 # mount -t ext2 -o ro,loop able2.part4.dd /mnt/analysis/usr
```

We now have the recreated original file system under */mnt/analysis*:

```
"/" (root)          mounted on /mnt/analysis
     |_ bin/
     |_boot/        mounted on /mnt/analysis/boot
     |_dev/
     |_etc/
     |_home/
     |_lib/
     |_opt/
     |_proc/
     |_usr/         mounted on /mnt/analysis/usr
     |_root/
     |_sbin/
     |_tmp...
```

At this point we can run all of our searches and commands just as we did for the previous floppy disk exercise on a complete file system “rooted” at */mnt/analysis*.

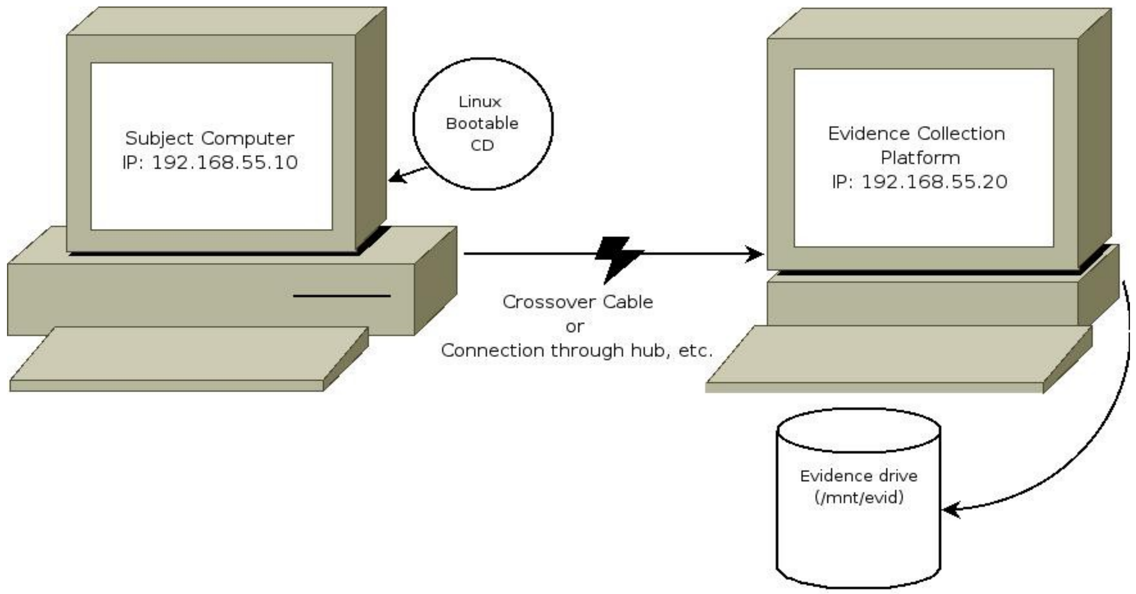
As always, you should know what you are doing when you mount a complete file system on your forensic workstation. Be aware of options to the **mount** command that you might want to use (check **man mount** for options like “*nodev*” and “*nosuid*”, “*noatime*” etc.). Take note of where links point to from the subject file system. Note that we have mounted the partitions “read only” (**ro**). Remember to unmount each partition when you are finished exploring.

DD Over the Wire

There may occasions where you want or need to acquire an image of a computer using a boot disk and network connectivity. Most often, this approach is used with a Linux boot disk on the subject machine (the machine you are going to image). Another computer, the imaging collection platform, is connected either via a network hub or switch; or through a crossover cable. There are a variety of configurations possible. These sorts of acquisitions can even take place across the country or anywhere around the world. The reasons and applications of this approach are outside of the scope of this paper, so we will concentrate on the mechanics and the very basic commands required.

First, lets clarify some terminology for the purpose of our discussion here. In this instance, the computer we want to image will be referred to as the “subject” computer. The computer to which we are writing the image will be referred to as the “collection” box.

In order to accomplish imaging across the network, we will need to setup our collection box to “listen” for data from our subject box. We do this using netcat, the **nc** command. The basic setup looks like this:



The first step is to open a "listening" port on the collection computer. We will do this on our forensic system with **nc**:

```
root@rock: ~ # nc -l -p 2525 | dd of=/mnt/evid/net_image.dd
```

This command opens a listening session (**-l**) on TCP port 2525 (**-p 2525**) and pipes any traffic that comes across that port to the **dd** command (with only the "output file" flag), which writes the file */mnt/evid/net_image.dd.*

Next, on the subject computer (note that the command prompt identifies this a computer with the hostname "bootdisk"), we issue the **dd** command. Instead of giving the command an output file parameter using **of=**, we pipe the **dd** command output to netcat (**nc**) and send it to our listening port (**2525**) on the collection computer at IP address **192.166.55.20**.

```
root@bootdisk ~ # dd if=/dev/sda | nc 192.168.55.20 2525
```

This command pipes the output of **dd** straight to **nc**, directing the image over the network to TCP port 2525 on the host 192.168.5.20 (our collection box's IP address). If you want to use **dd** options like **conv=noerror,sync** or **bs=x**, then you do that on the **dd** side of the pipe:

```
root@bootdisk ~ # dd if=/dev/sda bs=4096 | nc 192.168.55.20 2525
```

Once the imaging is complete, we will see that the commands at both ends appear to “hang”. After we receive our completion messages from **dd** on the subject box (*records in / records out),* we can kill the **nc** listening on our collection box with a simple *ctrl c.* This should return our prompts on both sides of the connections. You should then check both the hash of the physical disk that was imaged on the subject computer and the resulting image on the collection box to see if they match.

X. Advanced Forensic Tools

So now you have some experience with using the Linux command line and the powerful tools that are provided with a Linux installation. However, as forensic examiners, we soon come to find out that time is a valuable commodity. While learning to use the command line tools native to a Linux install is useful for a myriad of tasks in the "real world", it can also be tedious. After all, there are Windows based tools out there that allow you to do much of what we have discussed here in a simple point and click GUI. Well, the same can be said for Linux.

The popularity of Linux is growing at a fantastic rate. Not only do we see it in an enterprise environment and in big media, but we are also starting to see its widening use in the field of computer forensics. In recent years we've seen the list of available forensic tools for Linux grow with the rest of the industry.

In this section we will cover a number of forensic tools available to make your analysis easier and more efficient. We will cover both free tools and commercial tools. We will start with some alternative imaging tools, specially designed to work with forensic acquisitions in mind.

> AUTHOR'S NOTE: Inclusion of tools and packages in this section in no way constitutes an endorsement of those tools. Please test them yourself to ensure that they meet your needs. The tools here were chosen because it was suggested by a large number of readers of the original Introduction document that I provide information on forensic packages for Linux.
>
> Since this is a Linux document, I am covering available Linux tools. This does not mean that the common tools available for other platforms cannot be used to accomplish many of the same results. On a personal note, I do maintain that analysis of a Unix system is best accomplished with a Unix (like) tool set.

One more note: Please keep in mind, as you work through these exercises, this document is NOT meant to be an education in file system analysis. As you work through the exercises you will come across terms like *inode, MFT entry, allocation status, partition tables* and *direct and indirect blocks,* etc. These exercises are about using the tools, and are not meant to instruct you on basic forensic knowledge, Linux file systems or any other file systems. This is all about the *tools.*

If you need to learn file system structure as it relates to computer forensics, please read Brian Carrier's book: File System Forensic Analysis

(Published by Addison-Wesley, 2005). This is not the last time I will suggest this.

To get a quick overview of some file systems, you can do a quick Internet search. There is a ton of information readily available if you need a primer. Here are some simple links to get you started[13]. If you have questions on any of these file systems, or how they work, I would suggest some light reading before diving into these exercises.

NTFS:	http://www.ntfs.com http://en.wikipedia.org/wiki/NTFS
EXT2/3:	http://e2fsprogs.sourceforge.net/ext2intro.html http://en.wikipedia.org/wiki/Ext3
FAT:	http://en.wikipedia.org/wiki/File_allocation_table

Also, once you install the Sleuthkit (covered in an upcoming section) you should have a look in the *./sleuthkit-3.xx/docs/* directory (or wherever the source is installed) for the Sleuthkit Implementation Notes (or *SKINs).* These files contain some excellent detailed information on file system structure.

[13] The author does not vouch for any of these sources. They are provided for your information only.

Alternative Imaging Tools

Standard Linux **dd** is a fine imaging tool. It is robust, well tested, and has a proven track record. We've already demonstrated some of it's capabilities beyond what many consider “normal” forensic imaging functions.

As good as **dd** is as an imaging tool, it has one simple, perceived flaw: It was never actually designed to be used for forensic acquisitions. It is very capable, but some practitioners prefer full featured imaging tools that do not require external programs to accomplish logging, hashing, and imaging error documentation. Additionally, **dd** is not the best solution for obtaining evidence from damaged or failing media.

There are a number of forensic specific tools out there for Linux users that wish to acquire evidence. Some of these tools include:

- **dc3dd** -enhanced **dd** program for forensic use (based on **dd** code).
- **dcfldd** – enhanced dd program for forensic use (fork of **dd** code).
- **aimage** – forensic imaging tool provided primarily to create images in the Advanced Forensic Format (AFF). Future versions of this guide will likely cover **aimage** and *afflib* in more detail.
- **ewfacquire –** Provided as part of the *libewf* project, this tool is used to acquire Expert Witness Format (EWF) images. We will cover it in some detail later.
- **AIR –** Automated Image and Restore, a GUI front end to both **dd** and **dcfldd.**
- **GNU ddrescue –** An imaging tool specifically designed to recover data from media exhibiting errors (not to be confused with **dd_rescue**).

This is not an exhaustive list. These, however, are the most commonly used (as far as I know). We will cover the first in the list (**dc3dd**) and the last in the list (**ddrescue**) in this document. Later on, in the section on Advanced Tools we will cover **ewfacqure**, installed as part of the *libewf* package.

dc3dd

The first tool we will cover is **dc3dd**. This is a newer imaging tool based on original (patched) code from **dd**. It is very similar to the popular **dcfldd** but provides a slightly different feature set. My choice of whether to cover either **dcfldd** or **dc3dd** is largely arbitrary. One of the reasons I decided to cover **dc3dd** here is it's relationship to recent **dd** code updates, including direct I/O capabilities. d**c3dd** is maintained by the DoD (Department of Defense) Cyber

Crime Center (other wise known as Dc3)[14] Regardless of which (**dc3dd** or **dcfldd**) you prefer, familiarity with one of these tools will translate very nicely to the other with some reading and experimentation, as they are very similar. While there are significant differences, many of the features we discuss in this section are common to both **dc3dd** and **dcfldd.**

The source package and more information for **dc3dd** can be found at http://dc3dd.sourceforge.net. That page also provides a good summary of the capabilities of **dc3dd** and it's overall intent.

Installation of **dc3dd** follows the same routine of most source packages available in Linux. These packages are commonly called "tarballs" and end with the *tar.gz* or *tar.bz2* extensions, depending on the method of compression. In general, once the "tarball" has been extracted, the common commands to compile and install the package are simply (from the extracted directory):

./configure
make
make install

So, once we have the package downloaded, we can extract the tarball in the same way we extracted any of the other *tar.gz* files we worked with:

```
root@rock:~# tar xzvf dc3dd-6.9.91.tar.gz
dc3dd-6.9.91/
dc3dd-6.9.91/.prev-version
dc3dd-6.9.91/.version
dc3dd-6.9.91/.vg-suppressions
dc3dd-6.9.91/.x-po-check
dc3dd-6.9.91/.x-sc_file_system
dc3dd-6.9.91/.x-sc_GPL_version
dc3dd-6.9.91/.x-sc_obsolete_symbols
dc3dd-6.9.91/.x-sc_prohibit_atoi_atof
<continues>
```

After the package has been extracted, we change into the resulting directory and then run a "configure script" to allow the program to ascertain our system configuration and prepare compiler options for our environment. We do this by issuing the command **./configure**:

[14]DCFLdd is also named for a DoD entity – the Defense Computer Forensics Lab.

```
root@rock:~# cd dc3dd-6.9.91/

root@rock:~/dc3dd-6.9.91# ./configure
checking build system type... i686-pc-linux-gnu
checking host system type... i686-pc-linux-gnu
configure: autobuild project... dc3dd
configure: autobuild revision... 6.9.91
configure: autobuild hostname... rockriver
configure: autobuild timestamp... 20080807-202619
checking for a BSD-compatible install... /usr/bin/ginstall -c
checking whether build environment is sane...
<continues>
```

Assuming no errors, we type **make** and watch the compiler go to work.

```
root@rock:~/dc3dd-6.9.91# make
Making all in lib
make[1]: Entering directory `/root/Tools/dc3dd-6.9.91/lib'
{ echo '/* DO NOT EDIT! GENERATED AUTOMATICALLY! */'; \
        cat ./alloca.in.h; \
      } > alloca.h-t
mv -f alloca.h-t alloca.h
rm -f configmake.h-t configmake.h
{ echo '/* DO NOT EDIT! GENERATED AUTOMATICALLY! */'; \
<continues>
```

Finally, in order to call the various tools without using the full path to the compiled binaries, we must run the command that properly installs both the tools to the proper path, and any required libraries to the proper directories. This is accomplished with **make install**.

```
root@rock:~/dc3dd-6.9.91# make install
Making install in lib
make[1]: Entering directory `/root/Tools/dc3dd-6.9.91/lib'
make  install-am
make[2]: Entering directory `/root/Tools/dc3dd-6.9.91/lib'
make[3]: Entering directory `/root/Tools/dc3dd-6.9.91/lib'
test yes != no || /bin/sh /root/Tools/dc3dd-6.9.91/build-aux/install-sh
-d /usr/local/lib
if test -f /usr/local/lib/charset.alias; then \
<continues>
```

Our tool is now installed and ready to use.

One point to ponder if you are looking for the **man** page for **dc3dd**: The install routine does not copy the **man** page to the correct default location on our Slackware system (other OS versions may very). However, the **dc3dd** man page is essentially the same as the information provided by the **--help** option.

So, you can either run **dc3dd** with the **--help** option, or you can copy the **man** page file to the correct location[15]:

```
root@rock:~/dc3dd-6.9.91# cp man/dc3dd.1 /usr/local/man/man1/

root@rock:~/dc3dd-6.9.91# man dc3dd

DD(1)    User Commands    DD(1 )

NAME
       dd - convert and copy a file

SYNOPSIS
       dc3dd [OPERAND]...
       dc3dd OPTION
<continues>
```

OR simply:

```
root@rock:~/dc3dd-6.9.91# dc3dd --help
Usage: dc3dd [OPERAND]...
  or:  dc3dd OPTION
Copy a file, converting and formatting according to the operands.

  bs=BYTES        force ibs=BYTES and obs=BYTES
  cbs=BYTES       convert BYTES bytes at a time
<continues>
```

Since we are already talking about the help page, let's have a look at the basic usage of **dc3dd**. As you read through the usage section of the **man** page, you'll notice a number of additions to regular **dd** for the forensic examiner. Let's concentrate on these notables:

• *split=BYTES*	*split the output into pieces of size BYTES*
• *splitformat=FMT*	*create extensions for split pieces using FMT...*
• *progress=on*	*displays a progress meter*
• *hash=ALGORITHM*	*computes ALGORITHM hashes of the input data*
• *hashwindow=BYTES*	*number of bytes for piecewise hashing*
• *log=FILE*	*appends hashes and errors to the same file*
• *verifylog=FILE*	*write the results of the verify to the given file*

Essentially, **dc3dd** (and similarly **dcfldd**) has incorporated the hashing, splitting and logging of our acquisition into a single command. All of this can be done with regular **dd** and external tools, but there is no doubt many practitioners prefer an integrated approach. The standard options available to the regular **dd** command still work with the forensic editions (**bs**, **skip**, **etc.**).

[15]Or adjust $MANPATH, etc

More than just incorporating the other steps into a single command, **dc3dd** extends the functionality. For example, using a regular **split** command with **dd** as we did in a previous exercise, we can either allow the default alphabetic naming convention of **split**, or pass the **-d** option to provide us with decimal extensions on our files. In contrast, **dc3dd** allows us to not only define the size of each split as an option to the imaging command without need for a piped command, but it also allows more granular control over the format of the extensions each split will have as part of its filename. So, to split a 6 GB disk into 2 GB images, I would simply pass:

split=2G

The extension following the output file name can be formatted with the **splitformat** option. This option allows us to specify alphabetical or numerical extensions from 1 to 4 characters in length. Numerical extensions can either begin from 1 or from 0. The number of characters passed with the option defines the length of the extension. The following table provides some examples:

Option	*Resulting extensions*
splitformat=aa	**.aa* (two alphabetic chars) **.ab* **.ac*
splitformat=aaaa	**.aaaa* (four alphabetic chars) **.aaab* **.aaac*
splitformat=000	**.000* (three numeric chars – starts with 000) **.001* **.002*
splitformat=111	**.001* (three numeric chars– starts with 001) **.002* **.003*

In addition, when using regular GNU **dd**, our hashing functions are performed external to the imaging, by either the **md5sum** or **sha1sum** commands, depending on the analyst preference. **dc3dd** allows the user to run BOTH hashes concurrently on an acquisition and log the hashes.

We select our hash algorithm with the option **hash=**, specifying any of md5, sha1, sha256, sha512, or a comma separated list of algorithms. In this way you can select multiple hash methods for a single image file. These will be written to a log file we indicate (or to standard output if no log is specified).

dc3dd also provides a *hashwindow* function. The **hashwindow=** option initiates "piecewise" hashing of the output, so you get a calculated hash over each specified number of bytes, which is then logged. This allows for a more granular view of the data integrity, should errors be encountered. The smaller the *hashwindow*, the better granular view you have of the data.

So, to specify a *hashwindow* of 16MB using both SHA1 and MD5, you would use the options:

hash=md5,sha1 hashwindow=16M

Both the *hashwindow* values and the hash of the total image will be recorded either to standard out (the terminal) or to a log file if one is specified. You can specify separate logs for error messages and hash values, or have both of them written to a single file. The options for logging are:

hashlog=*file*	hashes are written to this log file.
errlog=*file*	error messages are written to this file.
log=*file*	both hashes and error messages are consolidated in a single log file.

Below is an example of a very basic **dc3dd** command used to image a small 256MB thumb drive. Aside from the options covered above, we will also use the **progress=on** option. This option gives us a running count of the amount of data copied, as well as a running time and average data copied per second.

```
root@rock:~# dc3dd if=/dev/sda of=image.dc3dd progress=on hash=md5
hashwindow=32M split=64M splitformat=000 log=image.log.txt
<running>
5039104 bytes (4.8 M) copied, 2.07115 s, 2.3 M/s

<finished>
506880+0 records in
506880+0 records out
259522560 bytes (248 M) copied, 109.425 s, 2.3 M/s

root@rock:~# ls -lh
total 312M
-rw-r--r-- 1 root root  64M 2008-07-13 07:48 image.dc3dd.000
-rw-r--r-- 1 root root  64M 2008-07-13 07:48 image.dc3dd.001
-rw-r--r-- 1 root root  64M 2008-07-13 07:49 image.dc3dd.002
-rw-r--r-- 1 root root  56M 2008-07-13 07:49 image.dc3dd.003
-rw-r--r-- 1 root root  596 2008-07-13 07:49 image.log.txt
```

The options used above are:

if=/dev/sda	input file is /dev/sda
of=image.dc3dd	image is written to image.dc3dd (arbitrary extension).
progress=on	shows imaging progress as described above
hashwindow=32M	calculates a hash of the data every 32 megabytes
hash=md5	describes the hash algorithm(s) to be used for each hashwindow and for the total image.
split=64M	the image is split into 64 megabyte chunks.
splitformat=000	the extensions on each image split will be three numerical characters, starting from 0.
log=image.log.txt	both the calculated hash values and any error messages will be logged to the file *image.log.txt*

The resulting output (shown by our **ls** command above) gives us 4 split image files, with numerical extensions starting with *000.* We also have a log file of our hashes and any error messages, which we can view with **less** or **cat**:

```
root@rock:~# cat image.log.txt
md5 0- 33554432: 3ef3e1146490631d10399be537b548ae
md5 33554432- 67108864: 84fb1bb69b5b8a9dfd2c0f61b9ebb72d
md5 67108864- 100663296: 9b025ba1d8e7a96eb666d5252bfd53cb
md5 100663296- 134217728: cac15f6afd76e0f9fd6c6cea93444f01
md5 134217728- 167772160: 26b9b1a732e0cf07591578392371e353
md5 167772160- 201326592: dde2fa565d6ea1a26a73466e0909f7ee
md5 201326592- 234881024: 58f06dd588d8ffb3beb46ada6309436b
md5 234881024- 259522560: a3e41cf8b32332ff504775ba44f49f3a
md5 TOTAL: c90ee2dfd36eae3aafd5fac9b8d2eb70
506880+0 records in
506880+0 records out
259522560 bytes (248 M) copied, 109.425 s, 2.3 M/s
```

As previously discussed, the log file contains our hashes and our error messages. Each line in the log starts with the hash algorithm and the hashwindow data range, followed by the calculated hash. The last hash line (or lines, if multiple algorithms are specified), gives the hash over the total image, which can be compared to a device hash, for example, to authenticate an acquisition.

The log file ends with the standard **dd** output which shows the number of "records" read and written. Even though it is not really an "error" message, this information is normally written to *stderr* (standard error output), hence it's inclusion in an error log. The records are equivalent to the block size option. Since we did not specify an explicit block size, the default for this block device is used, which is 512 bytes.

One final note on **dc3dd**: Like regular **dd**, you can pass the option **conv=noerror,sync** to the command. This would allow our acquisition to read past any non-fatal disk errors and sync the output so that the resulting image might still be usable. While many practitioners suggest this option as a default for running **dd** related commands, I strongly urge against it. Some of the reasons for this will become more apparent in the following section on **ddrescue.** The bottom line is that if you need to use **conv=noerror,sync** then you are using the wrong tool.

Which brings us to **ddrescue.**

ddrescue

The real reason I decided to add a section to this document on alternative imaging tools was so that I could introduce **ddrescue**. Recent testing has shown that standard **dd** based tools are simply inadequate for acquiring disks that have a propensity for errors. This is NOT to say tools like **dd**, **dc3dd** or **dcfldd** are useless, - far from it. They are just not optimal for error recovery.

This section is not meant to provide an eduction on disk errors, media failure, or types of failure. Nor is it meant to imply that any tool is better or worse than any other. I will simply describe the basic functionality and leave it to the reader to pursue the details.

First, let's start with the some of the issues that arise with the use of common **dd** based tools. For the most part, these tools take a "linear" approach to imaging, meaning that they start at the beginning of the input file and read block by block until the end of the file is reached. When an error is encountered, the tool will either fail with an "input/output" error, or if a parameter such as **conv=noerror** is passed it will ignore the errors and attempt to read through them, continuing to read block by block until it comes across readable data again.

Obviously, simple failure ("giving up" when errors are encountered) is not good, as it means that any data in readable areas beyond the errors will be missed. The problem with ignoring the errors and attempting to read through them ("**conv=noerror**") is that we are further stressing a disk that is already possibly on the verge of complete failure. The fact of the matter is that you may only get one chance at reading a disk that is exhibiting "bad sectors". If there is an actual physical defect, the simple act of reading the bad areas may make matters worse, leading to disk failure before other viable areas of the disk are collected.

So, when we pass **conv=noerror** to an imaging command, we are actually asking our imaging tools to "grind through" the bad areas. Why not initially skip over the bad sections altogether, since in many cases recovery may be unlikely, and concentrate on recovering data from areas of the disk that are good? Once the "good" data is acquired, we can go back and attempt to collect data from the error areas.

In a nutshell, that is the philosophy behind **ddrescue**. Used properly, **ddrescue** will read the "healthy" portions of a disk first, and then fall back to recovery mode – trying to read data from "bad sectors". It does this through the use of some very robust logging, which allows it to resume any imaging job at any point, given a log file to work from.

Before we go any farther with a description, let's download and install **ddrescue** and have a look at it's options.

You can obtain **ddrescue** from:

http://www.gnu.org/software/ddrescue/ddrescue.html

Once the file is downloaded, we go through the same set of build and install commands we used for our previous "tarball" software archive. In this case, the file we obtain from the above site is a *tar.bz2* archive rather than a *tar.gz* archive. This simply means that the compression is **bzip2** rather than **gzip**. As a result, we use the **j** option with tar rather than the **z** option:

```
root@rock:~# tar xjvf ddrescue-1.8.tar.bz2
ddrescue-1.8/AUTHORS
ddrescue-1.8/COPYING
ddrescue-1.8/ChangeLog
ddrescue-1.8/INSTALL
ddrescue-1.8/Makefile.in
ddrescue-1.8/NEWS
<continues>
root@rock:~# cd ddrescue-1.8
root@rock:~/ddrescue-1.8# ./configure
creating config.status
creating Makefile
VPATH = .
...
CXXFLAGS = -Wall -W -O2
LDFLAGS =
OK. Now you can run make.
<continues>
```

```
root@rock:~/ddrescue-1.8# make
g++  -Wall -W -O2 -c -o arg_parser.o arg_parser.cc
g++  -Wall -W -O2 -c -o block.o block.cc
g++  -Wall -W -O2 -c -o ddrescue.o ddrescue.cc
g++  -Wall -W -O2 -c -o fillbook.o fillbook.cc
g++  -Wall -W -O2 -c -o logbook.o logbook.cc
g++  -Wall -W -O2 -c -o rescuebook.o rescuebook.cc
g++  -Wall -W -O2 -DPROGVERSION=\"1.8\" -c -o main.o main.cc
g++  -o ddrescue arg_parser.o block.o ddrescue.o fillbook.o logbook.o
rescuebook.o main.o

root@rock:~/ddrescue-1.8# make install
if test ! -d /usr/local/share/info ; then install -d
/usr/local/share/info ; fi
install -p -m 644 ./doc/ddrescue.info
/usr/local/share/info/ddrescue.info
install-info /usr/local/share/info/ddrescue.info /usr/local/share/info/
dir
if test ! -d /usr/local/bin ; then install -d /usr/local/bin ; fi
install -p -m 755 ./ddrescue /usr/local/bin/ddrescue
```

The documentation for **ddrescue** is excellent. The detailed manual is in an *info* page. The command **info ddrescue** will give you a great start understanding how this program works, including examples and the ideas behind the algorithm used. I'll run through the process here, providing a “forensic” perspective.

The first consideration when using *any* recovery software, is that the disk must be accessible by the Linux kernel. If the drive does not show up in the */dev* structure, then there's no way to get tools like **ddrescue** to work.

Next, we have to have a plan to recover as much data as we can from a bad drive. The prevailing philosophy of **ddrescue** is that we should attempt to get all the *good* data *first*. This differs from normal **dd** based tools, which simply attempt to get all the data at one time in a linear fashion. **ddrescue** uses the concept of “splitting the errors”. In other words, when an area of bad sectors is encountered, the errors are split until the “good” areas are properly imaged and the unreadable areas marked as bad. Finally, **ddrescue** attempts to retry the bad areas by re-reading them until we either get data or fail after a certain number of specified attempts.

There are a number of ingenious options to **ddrescue** that allow the user to try and obtain the most important part of the disk first, then move on until as much of the disk is obtained as possible. Areas that are imaged successfully need not be read more than once. As mentioned previously, this is made possible by some very robust logging. The log is written periodically during the imaging process, so that even in the event of a system crash the session can be restarted, keeping duplicate imaging efforts, and therefore disk access, to a minimum.

Given that we are addressing forensic acquisition here, we will concentrate all our efforts on obtaining the entire disk, even if it means multiple runs. The following examples will be used to illustrate how the most important options to **ddrescue** work for the forensic examiner. We will concentrate on detailing the imaging log used by **ddrescue** so that the user can see what is going on with the tool, and how it operates.

Let's look at a simple example of using **ddrescue** on media without errors, using a 1GB thumb drive. The simplest way to run **ddrescue** is by providing the input file, output file and a name for our log file. Note that there is no “if=” or “of=”. In order to get a good look at how the log file works, we'll interrupt our imaging process halfway through, check the log, and then resume the imaging.

```
root@rock:~# ddrescue /dev/sda image.sda.ddr ddrlog.txt
Press Ctrl-C to interrupt
Initial status (read from logfile)
rescued:         0 B,  errsize:       0 B,  errors:       0
Current status
rescued:    341312 kB,  errsize:       0 B,  current rate:    1835 kB/s
   ipos:    341312 kB,   errors:       0,   average rate:    3038 kB/s
   opos:    341312 kB
Copying data...
Interrupted by user
```

Here we used */dev/sda* as our input file, wrote the image to *image.sda.ddr,* and wrote the log to *ddrlog.txt.* Note the output shows the progress of the imaging by default, giving us a running count of the amount of data copied or “*rescued*”, along with a count of the number of errors encountered (in this case zero), and the imaging speed. I interrupted this process with the “ctrl-c” key combo after around 325MB (of 1GB) were copied.

Now lets have a look at our log:

```
root@rock:~# cat ddrlog.txt
# Rescue Logfile. Created by GNU ddrescue version 1.8
# current_pos  current_status
0x14580200     ?
#      pos        size  status
0x00000000  0x14580200  +
0x14580200  0x28852000  ?
```

The log shows us the current status of your acquisition[16]. Lines starting with a "*#*" are comments. There are two sections of note. The first non comment line shows the current status of the imaging while the second section (two lines, in this case) shows the status of various blocks of data. The values are in hexadecimal, and are used by **ddrescue** to keep track of those areas of the target device that have marked errors as well those areas that have already been successfully read and written. The status symbols (taken from the *info* page) are as follows:

Character	Meaning
?	non-tried
*	bad area non-trimmed
/	bad area non-split
-	bad hardware block(s)
+	finished

In this case we are concerned only with the '*?*' and the '+' (we'll get to the others later). Essentially, when the copying process is interrupted, the log is used to tell **ddrescue** where the copying left off, and what has already been copied (or otherwise marked). The first section (status) alone may be sufficient in this case, since **ddrescue** need only pickup where it left off, but in the case of a disk with errors, the block section is required so **ddrescue** can keep track of what areas still need to be retried as good data is sought among the bad.

Translated, our log would tell us the following:

```
# current_pos          current_status
0x14580200             ?
```

- *The current imaging process is copying ("?") data at byte offset 34131200 (0x14580200)*

```
#    pos        size         status
0x00000000  0x14580200  +
0x14580200  0x28852000  ?
```

- *The data block from offset 0 of size 34131200 bytes (0x14580200) has been successfully copied ("+").*
- *The data block from offset 341312000 (0x14580200) and 679813120 bytes in size (0x28852000) is currently being copied ("?").*

Note also that the size of our partially copied file matches the size of the block of data marked "finished" in our log file:

[16] The **ddrescue** *info* page has a very detailed explanation of the log file structure.

```
root@rock:~# ls -l image.sda.ddr
-rw-r--r-- 1 root root 341312000 2008-08-22 19:28 image.sda.ddr
```

We can continue and complete the copy operation now by simply re invoking the same command. By specifying the same input and output files, and by providing the log file, we tell **ddrescue** to continue where it left off:

```
root@rock:~# cat ddrlog.txt
# Rescue Logfile. Created by GNU ddrescue version 1.8
# current_pos  current_status
0x14580200     ?
#      pos        size  status
0x00000000  0x14580200  +
0x14580200  0x28852000  ?
```

The progress indicator starts at the input position (*ipos*) specified in the log, and continues from there. When finished, the log shows the fully completed image in the second section (marked again with a '+').

```
root@rock:~# ddrescue /dev/sda image.sda.ddr ddrlog.txt

Press Ctrl-C to interrupt
Initial status (read from logfile)
rescued:   341312 kB,  errsize:       0 B,  errors:       0
Current status
rescued:     1021 MB,  errsize:       0 B,  current rate:    1703 kB/s
   ipos:     1021 MB,   errors:       0,    average rate:    1966 kB/s
   opos:     1021 MB
Finished

root@rock:~# cat ddrlog.txt
# Rescue Logfile. Created by GNU ddrescue version 1.8
# current_pos  current_status
0x3CDD0400     +
#      pos        size  status
0x00000000  0x3CDD2200  +

root@rock:~# echo "ibase=16;3CDD2200" | bc
1021125120

root@rock:~# ls -l image.sda.ddr
-rw-r--r-- 1 root root 1021125120 2008-08-22 21:09 image.sda.ddr
```

The above session shows the completed **ddrescue** command along with the contents of the log, which shows the status line informing of a completed image, and the block list now with a single entry from offset 0 for a size of 1021125120 bytes (0x3cdd0400). The completed block size matches the size of our image. Note the **bc** command to convert the hex value to decimal.

So that provides us an easy overview of **ddrescue** on a simple acquisition with one interruption, but no errors.

Bad Sectors - ddrescue

We've introduced two new imaging tools, **dc3dd** and **ddrescue**. We've shown an example of each in a simple acquisition, and now we are going to have a look at using them to acquire media with errors. In this case we will use a small 1.2 GB IDE disk with 15 bad sectors. This is not an artificially created disk, but a disk with actual errors.

We'll start with **ddrescue** and then compare with the results of **dc3dd**. As previously discussed, one of the main reasons we would try to use **ddrescue** over regular **dd** or **dc3dd**, is that we can have it obtain the good data before trying to read all the bad sectors. This gives us a better chance of acquiring all of the readable portions of the disk. Recall that with **ddrescue**, we can make numerous passes, using the log file to determine what still needs to be read and added to our acquisition.

The plan:

- Use **ddrescue** to obtain **only** the portions of the disk that are “good”.
- Use the **ddrescue** log to go back at retry the “bad” areas, making 3 attempts at reading each bad sector. This is done without re-reading the whole disk.

So, using **ddrescue**, we'll do our first acquisition run, passing an option that tells it to avoid “splitting” the bad areas, and just reading the good. This means that instead of breaking the bad areas of the disk into smaller parts , down to the hardware sector size, **ddrescue** will simply skip them and mark them with an asterisk (“*”) in the log file.

We've attached our disk to an EIDE controller, and found that it is detected as */dev/hdf.* Now we run **ddrescue**:

```
root@rock:~# ddrescue -n /dev/hdf image.hdf.ddr ddrloghdf.txt

Press Ctrl-C to interrupt
Initial status (read from logfile)
rescued:         0 B,  errsize:       0 B,  errors:       0
Current status
rescued:    18350 kB,  errsize:       0 B,  current rate:    6291 kB/s
   ipos:    18350 kB,   errors:       0,    average rate:    6116 kB/s
   opos:    18350 kB
copying data...
```

The **-n** option tells **ddrescue** to not "trim" or retry the error areas. Once the imaging is complete we get:

```
root@rock:~# ddrescue -n /dev/hdf image.hdf.ddr ddrloghdf.txt

Press Ctrl-C to interrupt
Initial status (read from logfile)
rescued:     1281 MB,  errsize:   61440 B,  current rate:    33280 kB/s
   ipos:   850771 kB,   errors:      15,    average rate:    1930 kB/s
   opos:   850771 kB
Finished
```

Note the amount of data "rescued" is the size of our disk "1281 MB". The number of errors is listed as "15" and the size of the error areas is "61440 Bytes". One interesting note about the total "error size" is that it calculates to 4096 bytes per error (61440/15). If there were 15 bad sectors we would expect an error size of 7680 bytes (512*15). The difference is a result of "kernel caching", where the actual blocks read and written are multiples of the cache size. Obviously this is not desirable in a forensic acquisition (we want all the data we can get). We alleviate this issue by using "direct access", where we bypass kernel caching. More on this later.

Looking at our resulting log, *ddrloghdf.txt* (shortened for readability):

```
root@rock:~# cat ddrloghdf.txt
# Rescue Logfile. Created by GNU ddrescue version 1.8
# current_pos  current_status
0x32B5C000     +
#      pos        size  status
0x00000000  0x32B77000  +
0x32B77000  0x00000E00  /
0x32B77E00  0x00000200  -
0x32B78000  0x00049000  +
0x32BC1000  0x00000E00  /
0x32BC1E00  0x00000200  -
<snip>
0x38684000  0x00000E00  /
0x38684E00  0x00000200  -
0x38685000  0x14013000  +
```

The first non-comment line of the log indicates that we have a complete image from byte offset 0 through 850771968 (0x32B5C000). We then have our areas where errors were detected. The errors in the log of our as-of-yet incomplete image are in groups of three addresses, each marked with a different symbol. Using the second set in the above log, we see

```
0x32B78000  0x00049000  +  (finished copying, good data)
0x32BC1000  0x00000E00  /  (data in a "bad area" not yet split)
0x32BC1E00  0x00000200  -  (block is marked "bad")
```

At this point, I would make one suggestion, from a forensic perspective: It might be a good idea to save a copy of each log, as it's changed, between successive runs. The logging done by **ddrescue** is designed for recovery, not documenting a forensic acquisition. By saving the log to a different filename between runs, you will have created a more complete picture of the forensic image as it goes through the error splitting and re-reading process.

Back to our acquisition - now we need to go back and try and re read the areas that are marked as "non-split". We issue essentially the same command, using the same input and output file, and the same log file. This time we remove the **-n** option:

```
root@rock:~# ddrescue -d -r3 /dev/hdf image.hdf.ddr ddrloghdf.txt

Press Ctrl-C to interrupt
Initial status (read from logfile)
rescued:     1281 MB,  errsize:   61440 B,  errors:      15
Current status
rescued:     1281 MB,  errsize:   39936 B,  current rate:     2560 B/s
   ipos:   855198 kB,   errors:      19,    average rate:     4300 B/s
   opos:   855198 kB
splitting error areas...

rescued:     1281 MB,  errsize:    7680 B,  current rate:        0 B/s
   ipos:   946356 kB,   errors:      15,    average rate:      663 B/s
   opos:   946356 kB
Finished
```

The **-r3** option is passed because we want **ddrescue** to try and re-read the bad areas 3 times before actually marking them bad. We also pass the **-d** option to specify direct access, and avoid the caching issue.

The final results show that we have the same 15 error areas, but they have been split down to a total error size of 7680 bytes (15 x 512). Note that in this case, the errors were unrecoverable, even with 3 tries. The log now shows our completed image, without split areas, but with each bad sector identified:

```
root@rock:~# cat ddrloghdf.txt
# Rescue Logfile. Created by GNU ddrescue version 1.8
# current_pos  current_status
0x38684000     +
#      pos        size  status
0x00000000  0x32B77800  +
0x32B77800  0x00000200  -
<snip>
0x38684000  0x00000200  -
0x38684200  0x14013E00  +
```

There are only "finished" areas and "bad" areas left in our log. And the bad areas are each a single 512 byte sector (size is 0x00000200).

We should also note that our resulting image is already "synchronized". The bad areas of the image have been filled with null bytes. One interesting feature of **ddrescue** is the ability to "fill" the image bad areas with a character of your choice. This can be useful in an exam to differentiate between zero'd sectors copied from the original image, versus bad sectors synchronized during the acquisition. See **info ddrescue** for more details.

Bad Sectors – dc3dd

Now we'll have a look at the same imaging job with dc3dd, and have a look at the result. Let's start with our most common acquisition parameters:

```
root@rock:~# dc3dd if=/dev/hdf of=image.hdf.dc3dd progress=on hash=md5
hashwindow=32M log=dc3ddloghdf.txt conv=noerror,sync
850884608 bytes (811 M) copied, 757.63 s, 1.1 M/s
dc3dd: reading `/dev/hdf': Input/output error
1661884+0 records in
1661884+0 records out
850884608 bytes (811 M) copied, 758.599 s, 1.1 M/s
851187200 bytes (812 M) copied, 758.908 s, 1.1 M/s
dc3dd: reading `/dev/hdf': Input/output error
1662474+1 records in
1662475+0 records out
851187200 bytes (812 M) copied, 759.806 s, 1.1 M/s
851489280 bytes (812 M) copied, 760.118 s, 1.1 M/s
<snip>
2503752+120 records in
2503872+0 records out
1281982464 bytes (1.2 G) copied, 1208.11 s, 1 M/s
```

With **dc3dd**, we use the same command we did in our previous example. Like regular **dd**, the **conv=noerror,sync** option tells **dc3dd** to ignore any errors, attempt to read past them, and write zeros to the image in order to keep it "synchronized" with the original. The **sync** is important because it keeps data structures properly aligned and allows, for example, a file system within the image to be properly mounted (assuming the damaged areas are not critical).

Note that our output shows 120 records (blocks) read as errors, ignored and sync'd. Given that each record is 512 bytes (the default block size), the amount of data lost is 61440 bytes. The same "error size" as our original **ddrescue** run. Luckily, recent versions of programs based on **dd** (including **dc3dd**) have a flag that allows for direct access. Again, this direct flag is passed to avoid kernel caching (in this case, 4096 byte pages).

Re running our **dc3dd** command with the **iflag=direct**, we get the following:

```
root@rock:~# dc3dd if=/dev/hdf of=image.hdf.dc3dd progress=on hash=md5
hashwindow=32M log=dc3ddloghdf.txt conv=noerror,sync iflag=direct
850884608 bytes (811 M) copied, 757.63 s, 1.1 M/s
dc3dd: reading `/dev/hdf': Input/output error
1661884+0 records in
1661884+0 records out
850884608 bytes (811 M) copied, 758.599 s, 1.1 M/s
851187200 bytes (812 M) copied, 758.908 s, 1.1 M/s
dc3dd: reading `/dev/hdf': Input/output error
1662474+1 records in
1662475+0 records out
851187200 bytes (812 M) copied, 759.806 s, 1.1 M/s
<snip>
946356224 bytes (903 M) copied, 857.745 s, 1.1 M/s
2503857+15 records in
2503872+0 records out
1281982464 bytes (1.2 G) copied, 1160.53 s, 1.1 M/s
```

We've ended up with essentially the same result as our **ddrescue** acquisition. We now have 15 errors of 512 bytes. The **iflag** option is new to the **dd** code, upon which **dc3dd** is based. Note that this is one reason I elected to cover **dc3dd** rather than **dcfldd**[17]. As a result of the fact that **dcfldd** is a "fork" of **dd** code, it does not include a provision for a "direct" flag. One final option you might consider passing when dealing with errors and **dc3dd** is the **errors=group** option. This will suppress multiple lines of error output for consecutive errors, giving a much smaller log file in those cases where large numbers of consecutive sectors are marked as bad.

For the curious among you, the hashes for the **ddrescue** acquisition and the **dc3dd** acquisition do match.

So, what's the difference?

[17] Note that you can still do direct I/O with **dcfldd** by accessing the target device through */dev/raw*.

<u>Bad Sector Acquisition - Conclusions</u>

We acquired an IDE disk with what appears to be 15 bad sectors using two different tools. In this case, we arrived at the same result. So, asking the question again, what's the difference between the tools, and why select one over the other?

dc3dd is primarily a forensic imaging tool. It is designed specifically for acquiring images for examination. It's strength is in allowing a forensic analyst to control the output of the acquisition. It provides for very granular control over authentication, splitting, and forensic logging. It does handle errors, as we saw in the preceding section, but it is not specifically designed with a recovery algorithm in mind – it just reads from start to finish.

ddrescue is primarily a recovery tool. It is designed specifically for rescuing data from failing or damaged media. It's strength is in it's ability to acquire the maximum amount of data from damaged media without simply “grinding” through an already damaged disk. The logging, while not particularly “friendly”, is geared toward directing successive runs at the data, not forensic documentation. If you are looking to attempt to acquire the data found within “bad sectors”, you have a much better shot at it with **ddrescue**.

While the results obtained in these examples do little to highlight the differences in the tools, other than the interface, keep in mind that every piece of media that exhibits errors is different. The *degree* of the error is never apparent. As such, your mileage with each tool will vary greatly.

One possible approach to this problem, if you prefer using acquisition tools designed for forensics (like **dc3dd** or **dcfldd**) , would be to continue using your tool of choice, but *without* the **conv=noerror** option. Instead, let the acquisition fail if an error is found. You can then move to a tool like **ddrescue** to safely acquire whatever data is recoverable, with a chance at getting more than would otherwise be possible. Just keep in mind that if a disk *is* going bad, you may only have one shot at acquiring it.

LIBEWF - Working with Expert Witness Files

One of the more ubiquitous forensic image formats found in the computer forensic world is the Expert Witness or “EWF” format. A number of popular GUI tools provide images by default in this format, and there are many tools that can read, convert or work with these images.

We will explore a set of tools here, belonging to the **libewf** project, that provide the ability to create, view, convert and work with expert witness evidence containers. We cover **libewf** before the other advanced forensic tools because it needs to be installed *first* in order to supply the required libraries to our other forensic tools for supporting these image formats . The **libewf** tools and detailed project information can be found at:

https://www.uitwisselplatform.nl/projects/libewf/

Download the most current version and extract the contents of the “tarball”. Note we are using version 20080501 in this document:

```
root@rock:~# tar xzvf libewf-20080501.tar.gz
libewf-20080501/
libewf-20080501/Makefile.in
libewf-20080501/COPYING
libewf-20080501/depcomp
libewf-20080501/ltmain.sh
libewf-20080501/compile
libewf-20080501/ChangeLog
libewf-20080501/INSTALL
<continues>
```

Installation of **libewf** follows the same routine we used to previously install **dc3dd**. As always, read the “*INSTALL*” file in the extracted directory to ensure the package uses this common method. Recall the commands we use are:

./configure
make
make install

The first command configures the build environment, the second command calls the compiler and builds the tools, and the third command installs the tools (and libraries) to the proper locations.

```
root@rock:~# cd libewf-20080501

root@rock:~/libewf-20080501# ./configure
checking for a BSD-compatible install... /usr/bin/ginstall -c
checking whether build environment is sane... yes
checking for gawk... gawk
checking whether make sets $(MAKE)... yes
checking build system type... i686-pc-linux-gnu
<continues>
```

Again, assuming no errors, we type **make** and watch as the compiler does its thing:

```
root@rock:~/libewf-20080501# make
Making all in libewf
make[1]: Entering directory `/root/Tools/libewf-20080501/libewf'
make  all-am
make[2]: Entering directory `/root/Tools/libewf-20080501/libewf'
if /bin/sh ../libtool --tag=CC --mode=compile gcc -DHAVE_CONFIG_H -I.
-I. -I.  -I../include   -g -O2 -Wall -MT ewf_compress.lo -MD -MP -MF
".deps/ewf_compress.Tpo" -c -o ewf_compress.lo ewf_compress.c; \
<continue>
```

Our newly compiled tools are placed in the "*ewftools*" directory. We will cover the following tools briefly here:

- **ewfinfo**
- **ewfverify**
- **ewfexport**
- **ewfacquire**
- **ewfacquirestream**

Now we use **make install** to put the commands in the proper path:

```
root@rock:~/libewf-20080501# make install
Making all in libewf
make[1]: Entering directory `/root/libewf-20080501/libewf'
make  Making install in common
make[1]: Entering directory `/root/libewf-20080501/common'
make[2]: Entering directory `/root/libewf-20080501/common'
make[2]: Nothing to be done for `install-exec-am'.
make[2]: Nothing to be done for `install-data-am'.
make[2]: Leaving directory `/root/libewf-20080501/common'
make[1]: Leaving directory `/root/libewf-20080501/common'
Making install in libewf
<continue>
```

Once the installation is complete we can move straight to using the tools. Proper paths have already been set, and the libraries required by other programs to use the support of **libewf** are available. On some systems, you may run into an initial problem where calling a tool results in a “library not found” error. If that is the case on your particular system, simply run the command **ldconfig** and try again.

To start, let's talk about those situations where you've been provided a set of image files (or file) that were obtained using a popular Windows forensic tool. There will be times where you would like read the meta-data included with the images, verify the contents of the images, or export or convert the images to a bitstream (commonly referred to as “dd”) format. This is where the **libewf** tools come in handy. They operate at the Linux command line, don't require any other special software, license, or dongle and are very fast. We will use a copy of an NTFS practical exercise image we will use in our upcoming Sleuthkit exercises. This particular copy is in *EWF* format. The file can be obtained from:

http://www.LinuxLEO.com/Files/ntfs_pract.E01

The first thing we can do is run the **ewfinfo** command on the image file. This will return the meta-data from the image file that includes acquisition and media information. We learn the version of the software that the image was created with, along with the collection platform, date of acquisition, name of the examiner that created the image with the description and notes. Have a look at the output of **ewfinfo** on our E01 file:

```
root@rock:~# ewfinfo ntfs_pract.E01
ewfinfo 20080501 (libewf 20080501, zlib 1.2.3, libcrypto 0.9.8, libuuid)

Acquiry information
        Case number:             NTFS_Practical
        Description:             NTFS_pract
        Examiner name:           Joe Agent
        Evidence number:         NTFS_pract
        Notes:                   This is a practice Image (e01 format)
        Acquiry date:            26/06/2007 10:58:13
        System date:             26/06/2007 10:58:13
        Operating system used:   Windows XP
        Software version used:   5.04
        Password:                N/A

Media information
        Media type:              fixed disk
        Media is physical:       yes
        Amount of sectors:       1024000
        Bytes per sector:        512
        Media size:              524288000
        Error granularity:       64
        Compression type:        good (fast) compression
        GUID:                    7b4bd359-960b-e845-93b4-2ae39474fed4
        MD5 hash in file:        d3c4659e4195c6df1da3afdbdc0dce8f
```

Notice that the last line in the output provides us with an MD5 hash of the *data* in the file. Don't confuse this with the hash of the file itself. A file in EWF format stores the original data from the media that was imaged along with a series of CRC checks and meta-data. The hash of the E01 file will NOT match the hash of the original media imaged. The hash of the original media and therefore the data collected is recorded in the EWF file for later verification.

If we are given an E01 file, or a set of EWF files (E01, E02, etc.*)*, and we want to simply verify that the data within the file is consistent with the data collected at the time of imaging, we can use the **ewfverify** command. This command re-hashes the data contained within file (disregarding the meta-data) and compares the hash obtained with the “MD5 hash in file”.

You can see from our output below that the the *ntfs_pract.E01* file verifies without error. The hash obtained during the verification matches that stored within the file:

```
root@rock:~# ewfverify ntfs_pract.E01
ewfverify 20080501 (libewf 20080501, zlib 1.2.3, libcrypto 0.9.8, libuuid)

Verify started at: Tue Aug 21 10:07:07 2007

This could take a while.

Status: at 3%.
        verified 18 MB (19202048 bytes) of total 500 MB (524288000 bytes).
        completion in 32 second(s) with 15 MB/s (15887515 bytes/second).
... (edited for brevity)
Verify completed at: Tue Aug 21 10:07:10 2007

Read: 500 MB (524288000 bytes) in 3 second(s) with 166 MB/s (174762666
bytes/second).

MD5 hash stored in file:        d3c4659e4195c6df1da3afdbdc0dce8f
MD5 hash calculated over data:  d3c4659e4195c6df1da3afdbdc0dce8f

ewfverify: SUCCESS
```

Another useful tool in the *libewf* arsenal is **ewfexport**. This tool allows you to take an EWF file and convert it to a bitstream image file, essentially removing the meta-data and leaving us with the data.

It is interesting to note that **ewfexport** actually writes to standard output by default, making it suitable for piping to other commands. We can use the **-t** option to write to a file. Using the **ewfexport**'s ability to write to standard out, we see that we can actually convert the E01 file to bitstream and pipe the data directly to **md5sum** to obtain the same hash as we did with **ewfverify**:

```
root@rock:~# ewfexport ntfs_pract.E01 | md5sum
ewfexport 20080501 (libewf 20080501, zlib 1.2.3, libcrypto 0.9.8, libuuid)

Information for export required, please provide the necessary input
Start export at offset (0 >= value >= 524288000) [0]:
Amount of bytes to export (0 >= value >= 524288000) [524288000]:

Export started at: Tue Aug 21 10:11:26 2007
... (edited for brevity)
Status: at 71%.
        exported 357 MB (374439936 bytes) of total 500 MB (524288000 bytes).
        completion in 1 second(s) with 125 MB/s (131072000 bytes/second).

Export completed at: Tue Aug 21 10:11:29 2007

Written: 500 MB (524288000 bytes) in 3 second(s) with 166 MB/s (174762666
bytes/second).

d3c4659e4195c6df1da3afdbdc0dce8f  -
```

The **ewfexport** command first asks us for some information on what we want to export form the EWF file (default is start to end). The data is exported and piped through the md5sum command. The last line of output shows the expected MD5 hash for the data and the input file is shown as "**-**", signifying that the **md5sum** command was reading the standard output coming through the pipe.

If we want to export the EWF file to an bitstream image, we use the **-t** (for "target") option. In the command below, we create the file *ntfs_image.dd* using **ewfexport** and check the MD5 hash:

```
root@rock:~# ewfexport -t ntfs_image.dd ntfs_pract.E01
ewfexport 20080501 (libewf 20080501, zlib 1.2.3, libcrypto 0.9.8, libuuid)

Information for export required, please provide the necessary input
Start export at offset (0 >= value >= 524288000) [0]:
Amount of bytes to export (0 >= value >= 524288000) [524288000]:

Export started at: Tue Aug 21 10:13:51 2007

This could take a while.

Status: at 7%.
        exported 39 MB (40927232 bytes) of total 500 MB (524288000 bytes).
        completion in 13 second(s) with 35 MB/s (37449142 bytes/second).
... (edited for brevity)
Status: at 88%.
        exported 444 MB (466386944 bytes) of total 500 MB (524288000 bytes).
        completion in 0 second(s) with 125 MB/s (131072000 bytes/second).

Export completed at: Tue Aug 21 10:13:55 2007

Written: 500 MB (524288000 bytes) in 4 second(s) with 125 MB/s (131072000
bytes/second).

root@rock:~# md5sum ntfs_image.dd
d3c4659e4195c6df1da3afdbdc0dce8f  ntfs_image.dd
```

Here we have written n new file called *ntfs_image.dd*, a bitstream image file exported from *ntfs_pract.E01*. The hash obtained afterward matches the expected hash from our original EWF file.

Finally, we will have a quick look at the **ewfacquire** and **ewfacquirestream**. These two commands are used to create EWF files that can be used in other programs. The easiest way to describe how **ewfacquire** works is to watch it run. There are a number of options available with the command. To get a short list, just run the command by itself with no options. To obtain an image, simply issue the command with the name of the file or physical device you wish to image. The program will prompt you for required information, to be stored with the data in the EWF format:

```
root@rock:~# ewfacquire /dev/sdb
ewfacquire 20080501 (libewf 20080501, zlib 1.2.3, libcrypto 0.9.8, libuuid)

Acquiry parameters required, please provide the necessary input
Image path and filename without extension: /root/ntfs_ewf
Case number: 111-222
Description: Removable media (generic thumbdrive)
Evidence number: 1
Examiner name: Barry Grundy
Notes: Seized from subject
Media type (fixed, removable) [fixed]: removable
Volume type (logical, physical) [physical]: physical
Use compression (none, fast, best) [none]: fast
Use EWF file format (ewf, smart, ftk, encase1, encase2, encase3, encase4,
encase5, encase6, linen5, linen6, ewfx) [encase5]: encase5
Start to acquire at offset (0 >= value >= 524288000) [0]:
Amount of bytes to acquire (0 >= value >= 524288000) [524288000]:
Evidence segment file size in kbytes (2^10) (1440 >= value >= 2097152) [665600]:
The amount of sectors to read at once (64, 128, 256, 512, 1024, 2048, 4096,
8192, 16384, 32768) [64]:
The amount of sectors to be used as error granularity (1 >= value >= 64) [64]:
The amount of retries when a read error occurs (0 >= value >= 255) [2]:
Wipe sectors on read error (mimic EnCase like behavior) (yes, no) [yes]:

The following acquiry parameters were provided:
Image path and filename:        /root/ntfs_ewf.E01
Case number:                    111-222
Description:                    Removable media (generic thumbdrive)
Evidence number:                1
Examiner name:                  Barry Grundy
Notes:                          Seized from subject
Media type:                     removable
Volume type:                    physical
Compression used:               fast
EWF file format:                EnCase 5
Acquiry start offet:            0
Amount of bytes to acquire:     524288000
Evidence segment file size:     665600 kbytes
Block size:                     64 sectors
Error granularity:              64 sectors
Retries on read error:          2
Wipe sectors on read error:     yes

Continue acquiry with these values (yes, no) [yes]: yes

Acquiry started at: Tue Aug 21 10:21:55 2007
... (edited for brevity)
Acquiry completed at: Tue Aug 21 10:22:31 2007

MD5 hash calculated over data:  d3c4659e4195c6df1da3afdbdc0dce8f
```

In the above command session, user input is shown in bold. In places where there is no input provided, the defaults are used. Notice that **ewfacquire** gives you several options for image formats that can be specified. The file(s) specified by the user is given an E** extension and placed in the path directed by the user. Finally, an MD5 hash is provided at the end of the output for verification.

Last, but not least, **ewfacquirestream** acts much like **ewfacquire**, but allows for data to be gathered via standard input. The most obvious use for this is taking data passed by a program like **netcat**.

Recall our "DD over the Wire" exercise. In that exercise, the data was sent across the network from our SUBJECT computer (booted with a Linux bootdisk) using **dd** and netcat (**nc**) and to our listening netcat process on our collection box IP address and port:

Subject computer:

```
root@bootdisk~ # dd if=/dev/sda | nc 192.168.55.20 2525
```

...Once the data reached the destination collection computer, the listening netcat process piped the output to the **dd** command output string, and the file was written exactly as it came across, as a bitstream image. Remember that the command on the collection computer must be run first, so that it is "listening" for the data before the command is run on the subject computer.

Collection computer:

```
root@rock:~ # nc -l -p 2525 | dd of=/mnt/evid/net_image.dd
```

By using **ewfacquirestream**, we can create EWF files instead of a bitstream image. We simply pipe the output stream from netcat to **ewfacquirestream**. If we do not wish to have the program use default values, then we issue the command with options that define how we want the image made (sectors, hash algorithms, error handling, etc.) and what information we want stored. The command on the subject machine remains the same. The command on the collection box would look something like this (utilizing many of the command defaults):

Collection computer using ewfacquirestream:

```
root@rock:~ # nc -l -p 2525 | ewfacquirestream -C 111-222 -D 'removable
thumb drive' -e 'Barry Grundy' -E '1' -f encase5 -m removable -M physical
-N 'Seized from subject' -t /mnt/evid/net_image
```

This command takes the output from netcat (**nc**) and pipes it to **ewfacquirestream**.

- the case number is specified with **-C**
- the evidence description is given with **-D**
- the examiner given with **-e**
- evidence number with **-E**
- *encase5* format is specified with **-f encase5**
- the media type is given with **-m**
- the volume type is given with **-M**
- notes are provided with **-N**
- the target path and file name is specified with **-t *****/path/file***.

No extension is given, and **ewfacquirestream** automatically appends an E01 extension to the resulting file.

To get a complete list of options, look at the man pages, or run the command with the **-h** option.

Sleuthkit

The first of the recovery tools we will cover here is actually not a GUI tool at all, but rather a collection of command line tools.[18]

The Sleuthkit is written by Brian Carrier and maintained at http://www.sleuthkit.org. It is partially based on The Coroner's Toolkit (TCT) originally written by Dan Farmer and Wietse Venema. The Sleuthkit adds additional file system support (FAT and NTFS). Additionally, the Sleuthkit allows you to analyze various file system types regardless of the platform you are currently working on. The current version, as of this writing is 3.0x . Go to the "downloads" section of the Sleuthkit website (http://www.sleuthkit.org) and grab the latest copy. For the sake of simplicity, let's download the file to our */root* (root user's home) directory.

Note that with the release of version 3.x, there are a number of very significant changes to the Sleuthkit over previous versions. Most note worthy, as of the 2.x series, is the inclusion of direct support for full disk images (rather than just partitions) and split disk images. Also, there have been a number of significant changes in new 3.x version, including renamed tools and changes to the programs that affect the way deleted files are dealt with.

Let's start with a discussion of the tools first. Most of this information is readily available in the Sleuthkit documentation or on the Sleuthkit website.

The Sleuthkit's tools are organized by what the author calls a "layer" approach.

- Media management layer – **mmls, mmcat, mmstat**
- File system layer – **fsstat**
- File name layer ("Human Interface") – **fls, ffind**
- Meta data (inode) layer – **icat, ils, ifind, istat**
- Content (data) layer – **blkcalc, blkcat, blkls, blkstat**

We also have tools that address physical disks and tools that address the "journals" of some file systems.

- Journal tools **– jcat, jls**
- disk tools – **disk_stat, disk_reset**

[18] Note that I have removed the Autopsy section from this version of the guide. I find that I do not use Autopsy much at all. And trying to discuss a tool that you don't use often can be bothersome...especially in a classroom full of inquisitive students that are often smarter than the instructor.

Notice that the commands that correspond to the analysis of a given layer begin with a common letter. For example, the file system command starts with “fs”, and the inode (meta-data) layer commands start with “i” and so on.

If the “layer” approach referenced above seems a little confusing to you, you should take the time to read the Sleuthkit's *README.txt* file. The author does a fine job of defining and describing these layers and how they fit together for a forensic analysis. Understanding that the Sleuthkit tools operate at different layers is extremely important.

It should be noted here that the output of each tool is specifically tailored to the file system being analyzed. For example, the **fsstat** command is used to print file system details. The structure of the output and the descriptive fields change depending on the target file system. This will become apparent throughout the exercises.

In addition to the tools already mentioned, there are some miscellaneous tools included with the Sleuthkit that don't fall into the above categories:

- **sorter** – categorizes allocated and unallocated files based on type (images, executables, etc). Extremely flexible and configurable.
- **img_cat** – allows for the separation of meta-data and original data from image files (media duplication, not pictures).
- **img_stat** – provides information about a forensic image. The information it provides is dependent on the image format (*aff, ewf, etc.*).
- **hfind** – hash lookup tool. Creates and searches an indexed database.
- **sigfind** - searches a given file (forensic image, disk, etc.) for a hex signature at any specified offset (sector boundary).
- **mactime** – creates a time line of file activity. VERY useful for intrusion investigations where temporal relationships are critical.
- **srch_strings** – like standard BSD **strings** command, but with the ability to parse different encodings.

Sleuthkit Installation and System Prep

Installation is easy. You can simply un-tar the file then change in to the resulting directory:

```
root@rock:~# tar xzvf sleuthkit-3.0.0.tar.gz
sleuthkit-3.0.0/
sleuthkit-3.0.0/aclocal.m4
sleuthkit-3.0.0/CHANGES.txt
sleuthkit-3.0.0/config/
<continues>
root@rock:~# cd sleuthkit-3.0.0
root@rock:~/sleuthkit-3.0.0 #
```

Take a moment to read the included documentation (*README.txt* is a good place to start). We will continue with a short description in this document, but most of what you need to know is right there.

Compiling the tools has changed significantly as of version 2.50 of the Sleuthkit. Previously, the programs were compiled with a simple **make** command, and libraries that provided a number of features were simply included with the package. Now, the program is compiled and built "manually" so support for external libraries (and their versions) is up to the user. For example, the **libewf** package (covered earlier), which provides support for *Expert Witness* format images must be properly installed *before* installing the Sleuthkit if you want support for EnCase format images. This is why we covered **libewf** and installed it first.

As with the **libewf** package, the new versions of the Sleuthkit are compiled and installed using the same basic set of commands as other "tarball" source distributions. Inside the directory we extracted above, we use the commands:

./configure
make
make install

The first step is to "configure" the package for compilation. This is where support is added for our previously installed **libewf** package. Note the output of the command at the end of the configure process in the following output:

```
root@rock:~/sleuthkit-3.0.0 # ./configure
checking for a BSD-compatible install... /usr/bin/ginstall -c
checking whether build environment is sane... yes
checking for gawk... gawk
checking whether make sets $(MAKE)... yes
...
checking for libewf_open in -lewf... yes
configure: creating ./config.status
config.status: creating Makefile
<continues>
```

During the configure process you'll note the line (in bold above) that the Sleuthkit detected the **libewf** install and will include support, so that the tools can be used on *EWF* (.E01) files.

Next, we run the **make** command to compile the tools.

```
root@rock:~/sleuthkit-3.0.0 # make
Making all in tsk3
make[1]: Entering directory `/root/sleuthkit-3.0.0/tsk3'
make  all-recursive
make[2]: Entering directory `/root/sleuthkit-3.0.0/tsk3'
Making all in base
make[3]: Entering directory `/root/sleuthkit-3.0.0/tsk3/base'
source='md5c.c' object='md5c.lo' libtool=yes \
      depfile='.deps/md5c.Plo' tmpdepfile='.deps/md5c.TPlo' \
      depmode=gcc3 /bin/sh ../../config/depcomp \
<compiler output>
```

If you run into any problems, read the *INSTALL.txt* document. When the compiling is finished, you will find the Sleuthkit tools located in various *sleuthkit-3.x/tools/** directories. The **man** pages for each command are located in the *sleuthkit-3.x/man* directory.

At this point we are ready to complete the install:

```
root@rock:~/sleuthkit-3.0.0 # make install
Making install in tsk3
make[1]: Entering directory `/root/sleuthkit-3.0.0/tsk3'
Making install in base
make[2]: Entering directory `/root/sleuthkit-3.0.0/tsk3/base'
make[3]: Entering directory `/root/sleuthkit-3.0.0/tsk3/base'
make[3]: Nothing to be done for `install-exec-am'.
make[3]: Nothing to be done for `install-data-am'.
make[3]: Leaving directory `/root/sleuthkit-3.0.0/tsk3/base'
make[2]: Leaving directory `/root/sleuthkit-3.0.0/tsk3/base'
Making install in img
<continues>
```

This places the Sleuthkit commands in */usr/local/bin/* and the **man** (manual pages for each command) in */usr/local/man.* Various header file and libraries used by the system are also copied to the proper locations.

Sleuthkit Exercises

Since the very first versions of this document, one of the most commonly requested additions has always been a more complete introduction to the Sleuthkit tools. I have been asked many, many times to add more exercises that include more of the tools and some of the more common file systems encountered by the average investigator. So, to that end, I've added a couple of new comprehensive exercises and a more thorough explanation of the available tools.

We are going to start with a quick sample analysis using just a few of the Sleuthkit command line tools. Like all of the other exercises in this document, I'd suggest you follow along if you can. Using these commands on your own is the only way to really learn the techniques. Read the included **man** pages and play with the options to obtain other output. The image files used in the following examples are available for download. Get your hands on the keyboard and follow along.

Sleuthkit Exercise #1 – Deleted File Identification and Recovery

Let's start our tour of Sleuthkit with one of the tools introduced in version 2 of the Sleuthkit, **img_stat**. This command is used to display the forensic image attributes including the type of image, and the format.

If we run the command against our *able2.dd* image, we see the following output. Note that we are running the command from within the */root/able2* directory, so there's no need to provide the full path to the target image.

```
root@rock:~# cd able2
root@rock:~/able2 # img_stat able2.dd
IMAGE FILE INFORMATION
--------------------------------------------
Image Type: raw

Size in bytes: 345830400
root@rock:~/able2 #
```

Since this is just a **dd** image, we see that the “Image Type” is listed as “raw”, and we are given the size of the image in bytes.

Very quickly, let's split our *able2.dd* file and see what the output from **img_stat** looks like when run on split files. We are going to split the original image file */root/able2/able2.dd* into 100MB chunks (note that we use the *-d* option to get our splits numbered), then run **img_stat** on the splits:

```
root@rock:~/able2# split -d -b 100m able2.dd able2.split.
root@rock:~/able2 # ls -lh able2.split.0*
-rw-r--r--  1 root root 100M Mar 21 15:11 able2.split.00
-rw-r--r--  1 root root 100M Mar 21 15:11 able2.split.01
-rw-r--r--  1 root root 100M Mar 21 15:11 able2.split.02
-rw-r--r--  1 root root  30M Mar 21 15:12 able2.split.03
root@rock:~/able2 # img_stat able2.split.0*
IMAGE FILE INFORMATION
--------------------------------------------
Image Type: split

Size in bytes: 345830400
--------------------------------------------
Split Information:
able2.split.00  (0 to 104857599)
able2.split.01  (104857600 to 209715199)
able2.split.02  (209715200 to 314572799)
able2.split.03  (314572800 to 345830399)
```

So, in the first command above, we split the *able2.dd* file. We then do an **ls -lh** to see the resulting splits and their sizes. Finally, the Sleuthkit's **img_stat** command is executed, and we see that it recognizes the split files and gives us the byte offsets of each split.

Now let's have a look at a couple of the file system and file name layer tools, **fsstat** and **fls**. We will run them against our *able2* images. Keep in mind that in older versions of Sleuthkit, we needed to carve the partitions out of the image to use with the tools. As of version 2.00, Sleuthkit tools have been able to look directly at the whole disk image. An offset must still be passed to the tool in order to for it to see the target file system.

We have already used **sfdisk** to determine partition offsets within a **dd** image. Sleuthkit also comes with a tool, **mmls**, that does much the same thing, providing access to the partition table within an image, and giving the partition offsets in sector units. As with many of the Sleuthkit tools, there is a certain amount of "intelligence" built into the command. If you do not pass the proper image type (with the **-i** option) or the proper partition type (for example, specifying that this is a *dos* partition table with the **-t** option), Sleuthkit will attempt to guess the proper parameters. For the sake of correctness, we will use the options **-i** and **-t** to pass the image type (either split or raw) and the type partition table.

```
root@rock:~/able2 # mmls -i split -t dos able2.split.0*
DOS Partition Table
Sector: 0
Units are in 512-byte sectors

     Slot    Start        End          Length       Description
00:  -----   0000000000   0000000000   0000000001   Primary Table (#0)
01:  -----   0000000001   0000000056   0000000056   Unallocated
02:  00:00   0000000057   0000010259   0000010203   Linux (0x83)
03:  00:01   0000010260   0000112859   0000102600   Linux (0x83)
04:  00:02   0000112860   0000178694   0000065835   Linux Swap / Solaris
05:  00:03   0000178695   0000675449   0000496755   Linux (0x83)
```

For the sake of this analysis, the information we are looking for is located on the root partition (file system) of our image. Remember from our previous analysis of the able2 **dd** image that the root ("/") file system is located on the second partition (*able2.part2.dd* in the previous exercise). Looking at our **mmls** output, we can see that that partition starts at sector 10260 (actually numbered "*03*" in the **mmls** output, or *slot 00:01*).

So, we run the Sleuthkit **fsstat** command with **-o 10260** to gather file system information at that offset.

```
root@rock:~/able2 # fsstat -o 10260 able2.dd
FILE SYSTEM INFORMATION
--------------------------------------------
File System Type: Ext2
Volume Name:
Volume ID: 906e777080e09488d0116064da18c0c4

Last Written at: Sun Aug 10 14:50:03 2003
Last Checked at: Tue Feb 11 00:20:09 1997

Last Mounted at: Thu Feb 13 02:33:02 1997
Unmounted Improperly
Last mounted on:

Source OS: Linux
Dynamic Structure
InCompat Features: Filetype,
Read Only Compat Features: Sparse Super,

METADATA INFORMATION
--------------------------------------------
Inode Range: 1 - 12881
Root Directory: 2
Free Inodes: 5807

CONTENT INFORMATION
--------------------------------------------
Block Range: 0 - 51299
Block Size: 1024
Reserved Blocks Before Block Groups: 1
<continues>
```

The **fsstat** command provides type specific information about the file system located in a device or forensic image. As previously noted, we ran the **fsstat** command above with the option **-o 10260.** This specifies that we want information from the file system residing on the partition that starts at sector offset 10260.

We can get more information using the **fls** command. **fls** lists the file names and directories contained in a file system, or in a directory, if the meta-data identifier for a particular directory is passed. The output can be adjusted with a number of options, to include gathering information about deleted files. If you type "**fls**" on its own, you will see the available options (view the **man** page for a more complete explanation).

If you run the **fls** command with no options (other than the **-o** option to specify the file system), then by default it will run on the "root" directory (inode 2 on and EXT file system, MFT entry 5 on NTFS, etc.).

In other words, on an EXT file system, running:

```
root@rock:~/able2 # fls -o 10260 able2.dd
```

And:

```
root@rock:~/able2 # fls -o 10260 able2.dd 2
```

...will result in the same output. In the second command, the "**2**" passed at the end of the command means "root directory", which is run by default in the first command.

So, in the following command, we run **fls** and only pass **-o 10260**. This results in a listing of the contents of the root directory:

```
root@rock:~/able2 # fls -o 10260 able2.dd
d/d 11:     lost+found
d/d 3681:   boot
d/d 7361:   usr
d/d 3682:   proc
d/d 7362:   var
d/d 5521:   tmp
d/d 7363:   dev
d/d 9201:   etc
d/d 1843:   bin
d/d 1844:   home
d/d 7368:   lib
d/d 7369:   mnt
d/d 7370:   opt
d/d 1848:   root
d/d 1849:   sbin
r/r 1042:   .bash_history
d/d 11105:  .001
d/d 12881:  $OrphanFiles
```

There are several points we want to take note of before we continue. Let's take a few lines of output and describe what the tool is telling us. Have a look at the last three lines from the above **fls** command.

```
...
r/r 1042:   .bash_history
d/d 11105:  .001
d/d 12881:  $OrphanFiles
```

Each line of output starts with two characters separated by a slash. This field indicates the file type as described by the file's directory entry, and the file's meta-data (in this case, the inode). For example, the first file listed in the snippet above, *.bash_history,* is identified as a regular file in both the file's directory and inode entry. This is noted by the *r/r* designation. Conversely, the following two entries (*.001* and *$OrphanFiles*) are identified as directories.

The next field is the meta-data entry number (inode, MFT entry, etc.) followed by the filename. In the case of the file *.bash_history* the inode is listed as *1042*.

Note that the last line of the output, *$OrphanFiles* is a virtual folder, created by the Sleuthkit and assigned a virtual inode (a new feature for Sleuthkit 3.00). This folder contains virtual file entries that represent unallocated meta data entries where there are no corresponding file names. These are commonly referred to as "orphan files", which can be accessed by specifying the meta data address, but not through any file name path. We will cover this in more detail in a later section.

We can continue to run **fls** on directory entries to dig deeper into the file system structure (or use **-r** for a recursive listing). By passing the meta data entry number of a directory, we can view it's contents. Read **man fls** for a look at some useful features. For example, have a look at the *.001* directory in the listing above. This is an unusual directory and would cause some suspicion. It is hidden (starts with a "."), and no such directory is common in the root of the file system. So, to see the contents of the *.001* directory, we would pass its inode to **fls**:

```
root@rock:~/able2 # fls -o 10260 able2.dd 11105
r/r 2138:   lolit_pics.tar.gz
r/r 11107:  lolitaz1
r/r 11108:  lolitaz10
r/r 11109:  lolitaz11
r/r 11110:  lolitaz12
r/r 11111:  lolitaz13
r/r 11112:  lolitaz2
r/r 11113:  lolitaz3
r/r 11114:  lolitaz4
r/r 11115:  lolitaz5
r/r 11116:  lolitaz6
r/r 11117:  lolitaz7
r/r 11118:  lolitaz8
r/r 11119:  lolitaz9
```

The contents of the directory are listed. We will cover commands to help view and analyze the individual files later on.

fls can also be useful for uncovering deleted files. By default, **fls** will show both allocated and unallocated files. We can change this behavior by passing other options. For example, if we wanted to see only deleted entires that are listed as files (rather than directories), and we want the listing to be recursive, we could use the following command:

```
root@rock:~/able2 # fls -o 10260 -Frd able2.dd
r/r * 11120(realloc):   var/lib/slocate/slocate.db.tmp
r/r * 10063:    var/log/xferlog.5
r/r * 10063:    var/lock/makewhatis.lock
r/r * 6613:     var/run/shutdown.pid
r/r * 1046:     var/tmp/rpm-tmp.64655
r/r * 6609(realloc):    var/catman/cat1/rdate.1.gz
r/r * 6613:     var/catman/cat1/rdate.1.gz
r/r * 6616:     tmp/logrot2V6Q1J
r/r * 2139:     dev/ttYZ0/lrkn.tgz
d/r * 10071(realloc):   dev/ttYZ0/lrk3
r/r * 6572(realloc):    etc/X11/fs/config-
l/r * 1041(realloc):    etc/rc.d/rc0.d/K83ypbind
l/r * 1042(realloc):    etc/rc.d/rc1.d/K83ypbind
l/r * 6583(realloc):    etc/rc.d/rc2.d/K83ypbind
l/r * 6584(realloc):    etc/rc.d/rc4.d/K83ypbind
l/r * 1044:     etc/rc.d/rc5.d/K83ypbind
l/r * 6585(realloc):    etc/rc.d/rc6.d/K83ypbind
r/r * 1044:     etc/rc.d/rc.firewall~
r/r * 6544(realloc):    etc/pam.d/passwd-
r/r * 10055(realloc):   etc/mtab.tmp
r/r * 10047(realloc):   etc/mtab~
r/- * 0:        etc/.inetd.conf.swx
r/r * 2138(realloc):    root/lolit_pics.tar.gz
r/r * 2139:     root/lrkn.tgz
r/r * 1055:     $OrphanFiles/OrphanFile-1055
r/r * 1056:     $OrphanFiles/OrphanFile-1056
r/r * 1057:     $OrphanFiles/OrphanFile-1057
r/r * 2141:     $OrphanFiles/OrphanFile-2141
r/r * 2142:     $OrphanFiles/OrphanFile-2142
r/r * 2143:     $OrphanFiles/OrphanFile-2143
<continues>
```

In the above command, we run the **fls** command against the partition in *able2.dd* starting at sector offset 10260 (**-o 10260**)**,** showing only file entries (**-F**), descending into directories (**-r**), and displaying deleted entries (**-d**).

Notice that all of the files listed have an asterisk (*****) before the inode. This indicates the file is deleted, which we expect in the above output since we specified the **-d** option to **fls**. We are then presented with the meta-data entry number (inode, MFT entry, etc.) followed by the filename.

Have a look at the line of output for inode number 2138 (*root/lolit_pics.tar.gz*). The inode is followed by "*(realloc)*". Keep in mind that **fls** describes the *file name* layer. The "realloc" means that the file name listed is marked as unallocated, even though the meta data entry (2138) is marked as allocated. In other words...the inode from our deleted file may have been "reallocated" to a new file.

According to Brian Carrier:

> *"The difference comes about because there is a file name layer and a metadata layer. Every file has an entry in both layers and each entry has its own allocation status.*
>
> *If a file is marked as "deleted" then this means that both the file name and metadata entries are marked as unallocated. If a file is marked as "realloc" then this means that its file name is unallocated and its metadata is allocated.*
>
> *The latter occurs if:*
> > *- The file was renamed and a new file name entry was created for the*
> > *file, but the metadata stayed the same.*
> > *- NTFS resorted the names and the old copies of the name will be "unallocated" even though the file still exists.*
> > *- The file was deleted, but the metadata has been reallocated to a new file.*
>
> *In the first two cases, the metadata correctly corresponds to the deleted file name. In the last case, the metadata may not correspond to the name because it may instead correspond to a new file."*

In the case of inode 2138, it looks as though the "realloc" was caused by the file being moved to the directory *.001* (see the **fls** listing of *.001* on the previous page). This causes it to be deleted from it's current directory entry (*root/lolit_pics.tar.gz*) and a new file name created (*.001/lolit_pics.tar.gz).* The inode and the data blocks that it points to remain unchanged and in "allocated status", but it has been "reallocated" to the new name.

Let's continue our analysis exercise using a couple of meta data (inode) layer tools included with the Sleuthkit. In a Linux EXT type file system, an inode has a unique number and is assigned to a file. The number corresponds to the *inode table*, allocated when a partition is formatted. The inode contains all the meta data available for a file, including the modified/accessed/changed (*mac*) times and a list of all the data blocks allocated to that file.

If you look at the output of our last **fls** command, you will see a deleted file called *lrkn.tgz* located in the */root* directory (the last file in the output of our **fls** command, before the list of orphan files -recall that the asterisk indicates it is deleted):

```
...
r/r * 2139:     root/lrkn.tgz
...
```

The inode displayed by **fls** for this file is *2139*. This same inode also points to another deleted file in */dev* earlier in the output (same file, different location). We can find all the file names associated with a particular meta data entry by using the **ffind** command:

```
root@rock:~/able2 # ffind -o 10260 able2.dd 2139
* /dev/ttYZ0/lrkn.tgz
* /root/lrkn.tgz
```

Here we see that there are two file names associated with inode *2139*, and both are deleted, as noted again by the asterisk.

Continuing on, we are going to use **istat**. Remember that **fsstat** took a *file system* as an argument and reported statistics about that file system. **istat** does the same thing; only it works on a specified *inode* or meta data entry.

We use **istat** to gather information about inode *2139*:

```
root@rock:~/able2 # istat -o 10260 able2.dd 2139
inode: 2139
Not Allocated
Group: 1
Generation Id: 3534950564
uid / gid: 0 / 0
mode: rrw-r--r--
size: 3639016
num of links: 0

Inode Times:
Accessed:       Sun Aug 10 00:18:38 2003
File Modified:  Sun Aug 10 00:08:32 2003
Inode Modified: Sun Aug 10 00:29:58 2003
Deleted:        Sun Aug 10 00:29:58 2003

Direct Blocks:
22811 22812 22813 22814 22815 22816 22817 22818
22819 22820 22821 22822 22824 22825 22826 22827
<snip>...
32233 32234
```

This reads the inode statistics (**istat**), on the file system located in the *able2.dd* image in the partition at sector offset 10260 (**-o 10260**), from inode **2139** found in our **fls** command**.** There is a large amount of output here, showing all the inode information and the file system blocks ("Direct Blocks") that contain all of the file's data. We can either pipe the output of **istat** to a file for logging, or we can send it to **less** for viewing.

Keep in mind that the Sleuthkit supports a number of different file systems. **istat** (along with many of the Sleuthkit commands) will work on more than just an EXT file system. The descriptive output will change to match the file system **istat** is being used on. We will see more of this a little later. You can see the supported file systems by running **istat** with "**-f list**".

```
root@rock:~/able2 # istat -f list
Supported file system types:
      ntfs (NTFS)
      fat (FAT (Auto Detection))
      ext (ExtX (Auto Detection))
      iso9660 (ISO9660 CD)
      ufs (UFS (Auto Detection))
      raw (Raw Data)
      swap (Swap Space)
      fat12 (FAT12)
      fat16 (FAT16)
      fat32 (FAT32)
      ext2 (Ext2)
      ext3 (Ext3)
      ufs1 (UFS1)
      ufs2 (UFS2)
```

We now have the name of a deleted file of interest (from **fls**) and the inode information, including where the data is stored (from **istat**).

Now we are going to use the **icat** command from the Sleuthkit to grab the actual data contained in the data blocks referenced from the inode. **icat** also takes the "inode" as an argument and reads the content of the data blocks that are assigned to that inode, sending it to standard output. Remember, this is a *deleted* file that we are recovering here.

We are going to send the contents of the data blocks assigned to inode *2139* to a file for closer examination.

```
root@rock:~/able2 # icat -o 10260 able2.dd 2139 > /root/lrkn.tgz.2139
```

This runs the **icat** command on the file system in our *able2.dd* image at sector offset *10260* (**-o 10260**) and streams the contents of the data blocks associated with inode **2139** to the file */root/lrkn.tgz.2139*. The filename is arbitrary; I simply took the name of the file from **fls** and appended the inode number to indicate that it was recovered. Normally this output should be directed to some results or specified evidence directory.

Now that we have what we hope is a recovered file, what do we do with it? Look at the resulting file with the **file** command:

```
root@rock:~/able2 # file /root/lrkn.tgz.2139
/root/lrkn.tgz.2139: gzip compressed data, was "lrkn.tar", from Unix
```

Have a look at the contents of the recovered archive (pipe the output through **less**…it's long). Remember that the "**t**" option to the **tar** command lists the contents of the archive.

Don't just haphazardly extract an archive without knowing what it will write, or especially where[19]

```
root@rock:~/able2 # tar tzvf /root/lrkn.tgz.2139 | less
drwxr-xr-x lp/lp             0 1998-10-01 18:48:18 lrk3/
-rwxr-xr-x lp/lp           742 1998-06-27 11:30:45 lrk3/1
-rw-r--r-- lp/lp           716 1996-11-02 16:38:43 lrk3/MCONFIG
-rw-r--r-- lp/lp          6833 1998-10-03 05:02:15 lrk3/Makefile
-rw-r--r-- lp/lp          6364 1996-12-27 22:01:43 lrk3/README
-rwxr-xr-x lp/lp            90 1998-06-27 12:53:45 lrk3/RUN
drwxr-xr-x lp/lp             0 1998-10-01 18:08:50 lrk3/bin/
<continues>
```

We have not yet extracted the archive, we've just listed its contents. Notice that there is a *README* file included in the archive. If we are curious about the contents of the archive, perhaps reading the *README* file would be a good idea, yes? Rather that extract the entire contents of the archive, we will go for just the *README* using the following **tar** command:

```
root@rock:~/able2 # tar xzvfO /root/lrkn.tgz.2139 lrk3/README > /root/README.2139
lrk3/README
```

The difference with this **tar** command is that we specify that we want the output sent to *stdout* ("**O**" [capital letter "oh"]) so we can redirect it. We also specify the name of the file that we want extracted from the archive (**lrk3/README**). This is all redirected to a new file called */root/README.2139*.

If you read that file (use **less**), you will find that we have uncovered a "rootkit", full of programs used to hide a hacker's activity.

Briefly, let's look at a different type of file recovered by **icat**. The concept is the same, but instead of extracting a file, you can stream it's contents to

[19] Let's face it, it would be BAD to have an archive that contains a bunch of Trojans and other nasties (evil kernel source or libraries, etc.) overwrite those on your system. Be extremely careful with archives.

stdout for viewing. Recall our previous directory listing of the *.001* directory at inode 11105:

```
root@rock:~/able2 # fls -o 10260 able2.dd 11105
r/r 2138:   lolit_pics.tar.gz
r/r 11107:  lolitaz1
r/r 11108:  lolitaz10
<continues>
```

We can determine the contents of the (allocated) file with inode *11108*, for example, by using **icat** to stream the inode's data blocks through a pipe to the **file** command. We use the "-" to indicate that **file** is getting its input from the pipe:

```
root@rock:~/able2 # icat -o 10260 able2.dd 11108 | file -
/dev/stdin: JPEG image data, JFIF standard 1.02
```

The output shows that we are dealing with a jpeg image. So we decide to use the **display** command to show us the contents:

```
root@rock:~/able2 # icat -o 10260 able2.dd 11108 | display
```

This results in an image opening in a window, assuming you are running in a graphical environment and have *ImageMagick* installed, which provides the **display** utility.

Sleuthkit Exercise #2 – Physical String Search & Allocation Status

This is another section added in response to a number of questions I've received both in classes and via e-mail. In our original floppy disk image analysis, one of the exercises we completed was a physical search of the image for a set of strings. Once the strings were located, we viewed them with the **xxd** utility. That's just half the story. In the vast majority of real examinations you are going to want to find out (if possible) what file that string belonged to and whether or not that file is allocated or unallocated. That is the purpose of this exercise.

This is a far more advanced exercise, but the question is asked enough that I thought it was worth covering here. I realize this is a beginner level document, but these are important concepts. Even if you rely on GUI tools for your day to day forensic analysis, you should understand exactly how your tools calculate and display their findings. In some ways the Sleuthkit forces you to understand these concepts (or you don't get very far).

This time we are going to do a search for a single string in our Linux disk image *able2.dd*. Based on some information received elsewhere, we decide to search our image for the keyword "*Cybernetik*". Change to the directory containing our able2.dd image and use **grep** to search for the string:

```
root@rock:~/able2 # grep -abi Cybernetik able2.dd
10561603: *     updated by Cybernetik for linux rootkit
55306929:Cybernetik proudly presents...
55312943:Email: cybernetik@nym.alias.net
55312975:Finger: cybernetik@nym.alias.net
```

Recall that our **grep** command is taking the file *able2.dd* treating it a s a text file (**-a**) and searching for the string "*Cybernetik*". The search is case-insensitive (**-i**) and will output the byte offset of any matches (**-b**).

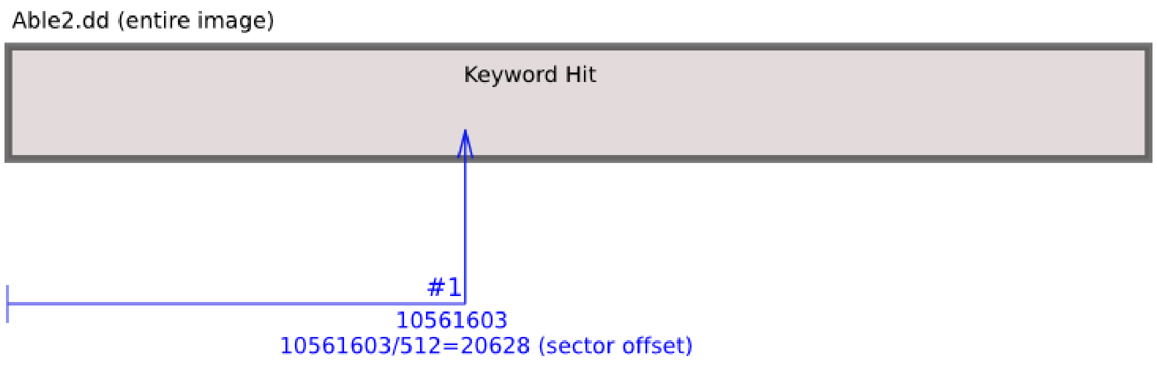
Our output shows that the first match comes at byte offset **10561603**. Like we did in our first string search exercise, we are going to quickly view the match using our hex viewer **xxd** and providing the offset given by **grep**. We will also use the **head** command to indicate that we only want to see a specific number of lines, in this case just 5 (**-n 5**). We just want to get a quick look at the context of the match before proceeding.

```
root@rock:~/able2 # xxd -s 10561603 able2.dd | head -n 5
0a12843: 202a 0975 7064 6174 6564 2062 7920 4379   *.updated by Cy
0a12853: 6265 726e 6574 696b 2066 6f72 206c 696e  bernetik for lin
0a12863: 7578 2072 6f6f 746b 6974 0a20 2a2f 0a0a  ux rootkit. */..
0a12873: 2369 6e63 6c75 6465 203c 7379 732f 7479  #include <sys/ty
0a12883: 7065 732e 683e 0a23 696e 636c 7564 6520  pes.h>.#include
```

We also have to keep in mind that what we have found is the offset to the match in the entire disk, not in a specific file system. In order to use the Sleuthkit tools, we need to have a file system to target.

Let's figure out which partition (and file system) the match is in. Use **bc** to calculate which sector of the image and therefore the original disk the keyword is in. Each sector is 512 bytes, so dividing the byte offset by 512 tells us which sector:

```
root@rock:~/able2 # echo "10561603/512" | bc
20628
```

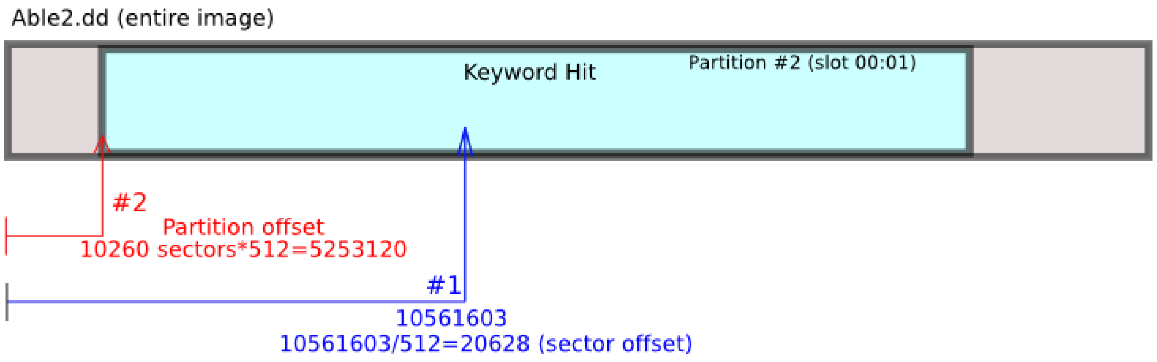


The Sleuthkit's **mmls** command gives us the offset to each partition in the image (you could also use **sfdisk**):

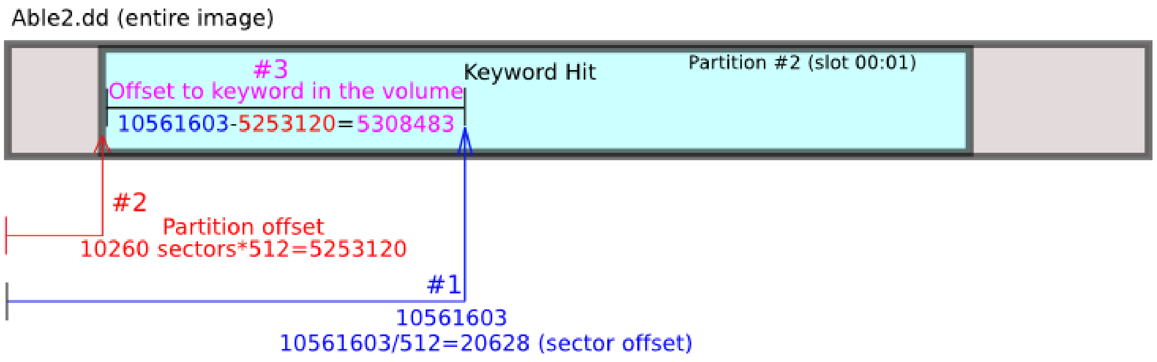
```
root@rock:~/able2 #  mmls able2.dd
DOS Partition Table
Offset Sector: 0
Units are in 512-byte sectors

     Slot     Start        End          Length       Description
00:  -----    0000000000   0000000000   0000000001   Primary Table (#0)
01:  -----    0000000001   0000000056   0000000056   Unallocated
02:  00:00    0000000057   0000010259   0000010203   Linux (0x83)
03:  00:01    0000010260   0000112859   0000102600   Linux (0x83)
04:  00:02    0000112860   0000178694   0000065835   Linux Swap /
Solaris x86 (0x82)
05:  00:03    0000178695   0000675449   0000496755   Linux (0x83)
```

From the output of **mmls** above, we see that our calculated sector, **20628**, falls in the second partition (between 10260 and 112859). The offset to our file system for the Sleuthkit commands will be **10260.**

The problem is that the offset that we have is the keyword's offset in the *disk image*, not in the file system (which is what the volume data block is associated with). So we have to calculate the offset to the file AND the offset to the partition that contains the file.


Able2.dd (entire image)
Keyword Hit
Partition #2 (slot 00:01)
#2
Partition offset
10260 sectors*512=5253120
#1
10561603
10561603/512=20628 (sector offset)

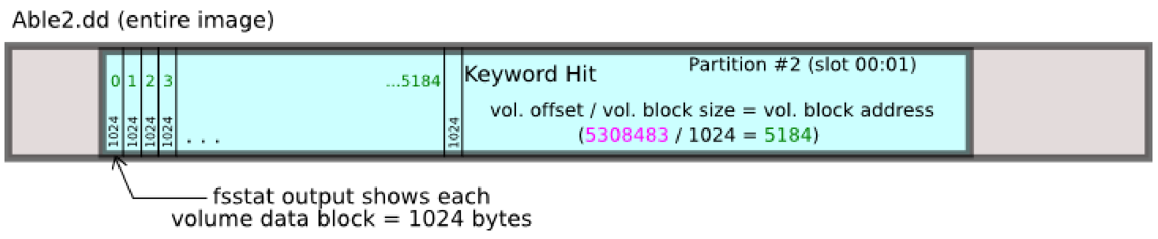
The difference between the two is the *volume offset* of the keyword hit, instead of the physical disk (or image) offset.


Able2.dd (entire image)
#3
Offset to keyword in the volume
10561603-5253120=5308483
Keyword Hit
Partition #2 (slot 00:01)
#2
Partition offset
10260 sectors*512=5253120
#1
10561603
10561603/512=20628 (sector offset)

Now we know the offset to the keyword within the actual volume, rather than the entire image. Let's find out what inode (meta-data unit) points to the volume data block at that offset. To find which inode this belongs to, we first have to calculate the volume data block address. Look at the Sleuthkit's **fsstat** output to see the number of bytes per block. We need to run **fsstat** on the file system at sector offset 10260:

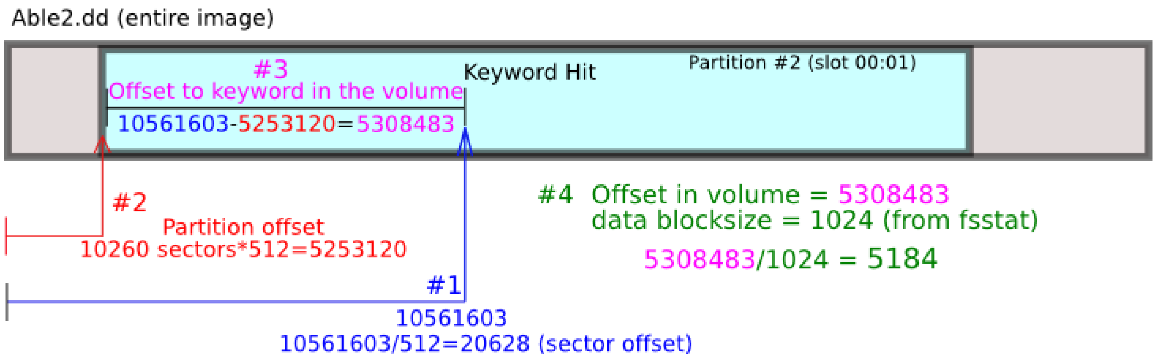
```
root@rock:~/able2 #  fsstat -o 10260 -f ext able2.dd
FILE SYSTEM INFORMATION
--------------------------------------------
File System Type: Ext2
Volume Name:
Volume ID: 906e777080e09488d0116064da18c0c4

Last Written at: Sun Aug 10 14:50:03 2003
Last Checked at: Tue Feb 11 00:20:09 1997

Last Mounted at: Thu Feb 13 02:33:02 1997
Unmounted Improperly
Last mounted on:

Source OS: Linux
Dynamic Structure
InCompat Features: Filetype,
Read Only Compat Features: Sparse Super,

METADATA INFORMATION
--------------------------------------------
Inode Range: 1 - 12881
Root Directory: 2
Free Inodes: 5807

CONTENT INFORMATION
--------------------------------------------
Block Range: 0 - 51299
Block Size: 1024
Reserved Blocks Before Block Groups: 1
Free Blocks: 9512

<continues>
```

The **fsstat** output shows us (highlighted in bold) that the data blocks within the volume are 1024 bytes each. If we divide the volume offset by 1024, we identify the data block that holds the keyword hit.


Able2.dd (entire image)
0 1 2 3
...5184
1024 1024 1024 1024
. . .
1024
Keyword Hit
Partition #2 (slot 00:01)
vol. offset / vol. block size = vol. block address
(5308483 / 1024 = 5184)
fsstat output shows each volume data block = 1024 bytes

Here are our calculations, summarized:

- offset to the string in the disk image (from our **grep** output)**: 10561603**
- offset to the partition that contains the file: **10260** sectors * 512 bytes per sector
- offset to the string in the partition is the difference between the two above numbers.
- the data block is the offset in the file system divided by the block size, (data unit size) **1024**, from our **fsstat** output.


Able2.dd (entire image)
#3
Offset to keyword in the volume
10561603-5253120=5308483
Keyword Hit
Partition #2 (slot 00:01)
#2
Partition offset
10260 sectors*512=5253120
#1
10561603
10561603/512=20628 (sector offset)
#4 Offset in volume = 5308483
data blocksize = 1024 (from fsstat)
5308483/1024 = 5184

In short, our calculation, taking into account all the illustrations above, is simply:

```
root@rock:~/able2 # echo "(10561603-(10260*512))/1024" | bc
5184
```

Note that we use parentheses to group our calculations. We find the byte offset to the file system first **(10260*512)**, subtract that from the offset to the string **(10561603)** and then divide the whole thing by the data unit size (**1024**) obtained from **fsstat.** This (**5184**) is our data unit (not the inode!) that contains the string we found with **grep**. Very quickly, we can ascertain its allocation status with the Sleuthkit command **blkstat**:

```
root@rock:~/able2 # blkstat -o 10260 -f ext able2.dd 5184
Fragment: 5184
Not Allocated
Group: 0
```

So **blkstat** tells us that our key word search for the string "*Cybernetik*" resulted in a match in an unallocated block. Now we use **ifind** to tell us which inode (meta-data structure) points to data block 5184 in the second partition of our image:

```
root@rock:~/able2 #  ifind -o 10260 -f ext -d 5184 able2.dd
10090
```

Excellent! The inode that holds the keyword match is **10090**. Now we use **istat** to give us the statistics of that inode:

```
root@rock:~/able2 # istat -o 10260 -f ext able2.dd 10090
inode: 10090
Not Allocated
Group: 5
Generation Id: 3534950782
uid / gid: 4 / 7
mode: -rw-r--r--
size: 3591
num of links: 0

Inode Times:
Accessed:       Sun Aug 10 00:18:36 2003
File Modified:  Wed Dec 25 16:27:43 1996
Inode Modified: Sun Aug 10 00:29:58 2003
Deleted:        Sun Aug 10 00:29:58 2003

Direct Blocks:
5184 5185 5186 5187
```

From the **istat** output we see that inode 10090 is unallocated (same as **blkstat** told us about the data unit) . Note also that the first direct block indicated by our **istat** output is 5184, just as we calculated.

We can get the data from the direct blocks of the original file by using **icat -r**. Pipe the output through **less** so that we can read it easier. Note that our keyword is right there at the top:

```
root@rock:~/able2 # icat -r -o 10260 -f ext able2.dd 10090 | less
/*
 *      fixer.c
 *      by Idefix
 *      inspired on sum.c and SaintStat 2.0
 *      updated by Cybernetik for linux rootkit
 */

#include <sys/types.h>
#include <sys/stat.h>
#include <sys/time.h>
#include <stdio.h>

main (argc,argv)
int     argc;
char    **argv;
<continues>
```

At this point, we have recovered the data we were looking for. We can run our **icat** command as above again, this time directing the output to a file (as we did with the rootkit file from our previous recovery exercise).

One additional note: With the release of Sleuthkit v3.x, we now have a virtual directory that contains entries for *orphan files*. As we previously noted, in our discussion of the **fls** command, these files are the result of an inode containing file data having no file name (directory entry) associated with it. Sleuthkit organizes these in the virtual *$OrphanFiles* directory. This is a useful feature because it allows us to identify and access orphan files from the output of the **fls** command.

In this exercise, we determined through our calculations that we were looking for the contents of inode *10090*. The Sleuthkit command **ffind** can tell us the file name associated with an inode. Here, we are provided with the *$OrphanFiles* entry:

```
root@rock:~/able2 # ffind -o 10260 able2.dd 10090
* /$OrphanFiles/OrphanFile-10090
```

Keep in mind that various file systems act very differently. Even between an Ext2 and Ext3 file system there are differences in how files are deleted. Sleuthkit will simply report what it finds to the investigator. It is up to YOU to properly interpret what you are shown.

Sleuthkit Exercise #3 – Unallocated Extraction & Examination

As the size of media being examined continues to grow, it is becoming apparent to many investigators that data reduction techniques are more important than ever. These techniques take on several forms, including hash analysis (removing known "good" files from a data set, for example) and separating allocated space in an image from unallocated space, allowing them to be searched separately with specialized tools. We will be doing the latter in this exercise.

The Sleuthkit comes with a set of tools for handling information at the "block" layer of the analysis model. The block layer consists of the actual file system blocks that hold the information we are seeking. They are not specific to unallocated data only, but are especially useful for working on unallocated blocks that have been extracted from an image. The tools that manipulate this layer, as you would expect, start with *blk* and include:

blkls
blkcalc
blkstat
blkcat

We will be focusing on **blkls**, **blkcalc** and **blkstat** for the next couple of exercises.

The tool that starts us off here is **blkls**. This command "lists all the data blocks". If you were to use the "**-e**" option, the output would be the same as the output of **dd** for that volume, since **-e** tells **blkls** to copy "every block". However, by default, **blkls** will only copy out the unallocated blocks of an image.

This allows us to separate allocated and unallocated blocks in our file system. We can use logical tools (**find**, **ls**, etc.) on the "live" files in a mounted file system, and concentrate data recovery efforts on only those blocks that may contain deleted or otherwise unallocated data. Conversely, when we do a physical search of the output of **blkls**, we can be sure that artifacts found are from unallocated content.

To illustrate what we are talking about here, we'll run the same exercise we did in Sleuthkit Exercise #2, this time extracting the unallocated data from our volume of interest and comparing the output from the whole volume analysis vs. unallocated analysis. So, we'll be working on the *able2.dd* image from earlier. We expect to get the same results we did in Exercise #2, but this time by analyzing *only* the unallocated space, and then associating the recovered data with its original location in the full disk image.

First we'll need to change into the directory containing our *able2.dd* image. Then we check the partition table and decide which volume we'll be examining. Recall that this is where we get our **-o** (offset) value from for our Sleuthkit commands. To do this, we run the **mmls** command :

```
root@rock:~/Able2# mmls able2.dd
DOS Partition Table
Offset Sector: 0
Units are in 512-byte sectors

     Slot    Start        End          Length       Description
00:  -----   0000000000   0000000000   0000000001   Primary Table (#0)
01:  -----   0000000001   0000000056   0000000056   Unallocated
02:  00:00   0000000057   0000010259   0000010203   Linux (0x83)
03:  00:01   0000010260   0000112859   0000102600   Linux (0x83)
04:  00:02   0000112860   0000178694   0000065835   Linux Swap...(0x82)
05:  00:03   0000178695   0000675449   0000496755   Linux (0x83)
```

As with Exercise #2, we've decided to search the unallocated space in the second Linux partition (at offset 10260, in bold above).

We run the **blkls** command using the offset option (**-o**) which indicates what partition's file system we are analyzing. We then redirect the output to a new file that will contain only the unallocated blocks of that particular volume.

```
root@rock:~/Able2# blkls -o 10260 able2.dd > able2.blkls

root@rock:~/Able2# ls -lh
total 9.4M
-rw-r--r-- 1 root root 9.3M 2008-06-09 09:40 able2.blkls
-rwxrwxr-x 1 root root 330M 2003-08-10 21:16 able2.dd
...
```

In the above command, we are using **blkls** on the second partition (**-o 10260**) within the *able2.dd* image, and redirecting the output to a file called *able2.blkls*. The file *able2.blkls* will contain only the unallocated blocks from the target file system.

Now, as we did in our previous analysis of this file system (Exercise #2) we will use **grep**, this time on the *extracted unallocated space*, our *able2.blkls* file, to search for our text string of interest. Read back through Exercise #2 if you need a refresher on these commands.

```
root@rock:~/Able2# grep -abi cybernetik able2.blkls
1631299: *      updated by Cybernetik for linux rootkit
9317041:Cybernetik proudly presents...
9323055:Email: cybernetik@nym.alias.net
9323087:Finger: cybernetik@nym.alias.net
```

The **grep** command above now tells us that we have found the string "cybernetik" at four different offsets in the extracted unallocated space. We will concentrate on the first hit here. Of course these are different from the offsets we found in Exercise #2 because we are no longer searching the entire original **dd** image.

So the next obvious question is "so what?". We found potential evidence in our extracted unallocated space. But how does it relate to the original image? As forensic examiners, merely finding potential evidence is not good enough. We also need to know where it came from (physical location in the original image), what file it belongs or (possibly) belonged to, meta data associated with the file, and context. Finding potential evidence in a big block of aggregate unallocated space is of little use to us if we cannot at least make some effort at attribution in the original file system.

That's where the other block layer tools come in. We can use **blkcalc** to calculate the location (by data block or fragment) in our original image. Once we've done that, we simply use the meta data layer tools to identify and potentially recover the original file, as we did in our previous effort.

First we need to gather a bit of data about the original file system. We run the **fsstat** command to determine the size of the data blocks we are working with.

```
root@rock:~/Able2# fsstat -o 10260 able2.dd
FILE SYSTEM INFORMATION
--------------------------------------------
File System Type: Ext2
Volume Name:
Volume ID: 906e777080e09488d0116064da18c0c4
...
CONTENT INFORMATION
--------------------------------------------
Block Range: 0 - 51299
Block Size: 1024
...
```

In the **fsstat** command above, we see that the block size (in bold) is *1024*. We take the offset from our **grep** output on the *able2.blkls* image and divide that by 1024. This tells us how many unallocated data *blocks* into the unallocated image we found our string of interest. We use the **echo** command to pass the math expression to the command line calculator, **bc**:

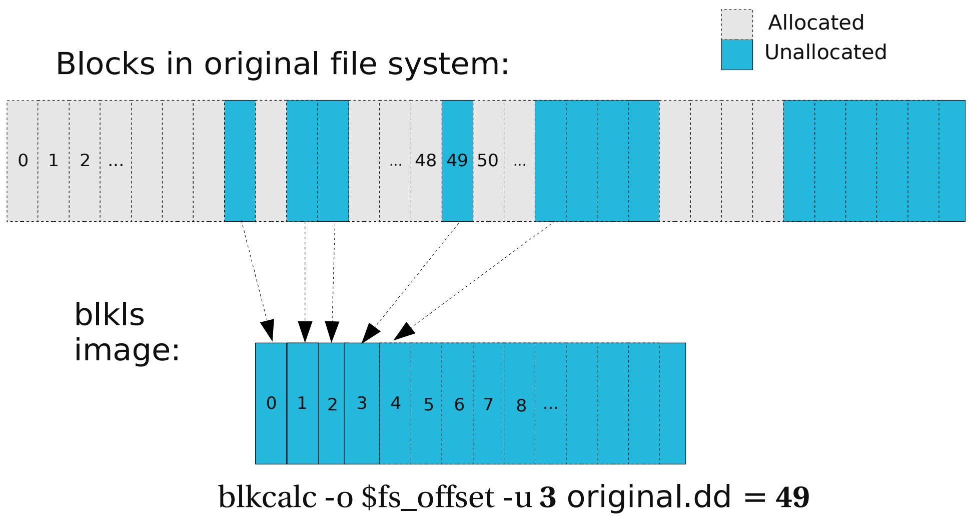
```
root@rock:~/Able2# echo "1631299/1024" | bc
1593
```

We now know, from the above output, that the string “cybernetik” is in data block 1593 of our extracted unallocated file, *able2.blkls*.

This is where our handy **blkcalc** command comes in. We use **blkcalc** with the **-u** option to specify that we want to calculate the block address from an extracted unallocated image (from **blkls** output). We run the command on the *original* **dd** image because we are calculating the orginal data block in that image.

```
root@rock:~/Able2# blkcalc -o 10260 -u 1593 able2.dd
5184
```

The command above is running **blkcalc** on the file system at offset *10260* (**-o 10260**) in the original *able2.dd*, passing the data block we calculated from the **blkls** image *able2.blkls* (**-u 1593**). The result is a familiar block *5184* (see Exercise #2 again). The illustration below gives a visual representation of a simple example:


Allocated
Unallocated
Blocks in original file system:
0
1
2
...
...
48
49
50
...
blkls image:
0
1
2
3
4
5
6
7
8
...
blkcalc -o $fs_offset -u 3 original.dd = 49

In the illustrated example above, the data in block #3 of the **blkls** image would map to block #49 in the original file system. We would find this with the

blkcalc command as shown (this is just an illustration, and does not apply to the current exercise):

```
root@rock:~/example# blkcalc -o $fs_offset -u 3 original.dd
49
```

So, in simple terms, we have extracted the unallocated space, found a string of interest in a data block in the unallocated image, and then found the corresponding data block in the original image.

If we look at the **blkstat** (data block statistics) output for block *5184* in the original image, we see that it is, in fact unallocated, which makes sense, since we found it within our extracted unallocated space (we're back to the same results as in Exercise #2). Note that we are now running the commands on the original **dd** image. We'll continue on for the sake of completeness.

```
root@rock:~/Able2# blkstat -o 10260 able2.dd 5184
Fragment: 5184
Not Allocated
Group: 0
```

Using the command **blkcat** we can look at the raw contents of the data block (using **xxd** and **less** as a viewer). If we want to, we can even use **blkcat** to extract the block, redirecting the contents to another file:

```
root@rock:~/Able2# blkcat -o 10260 able2.dd 5184 | xxd | less
0000000: 2f2a 0a20 2a09 6669 7865 722e 630a 202a  /*. *.fixer.c. *
0000010: 0962 7920 4964 6566 6978 200a 202a 0969  .by Idefix . *.i
0000020: 6e73 7069 7265 6420 6f6e 2073 756d 2e63  nspired on sum.c
0000030: 2061 6e64 2053 6169 6e74 5374 6174 2032   and SaintStat 2
0000040: 2e30 0a20 2a09 7570 6461 7465 6420 6279  .0. *.updated by
0000050: 2043 7962 6572 6e65 7469 6b20 666f 7220   Cybernetik for
0000060: 6c69 6e75 7820 726f 6f74 6b69 740a 202a  linux rootkit. *
0000070: 2f0a 0a23 696e 636c 7564 6520 3c73 7973  /..#include <sys
0000080: 2f74 7970 6573 2e68 3e0a 2369 6e63 6c75  /types.h>.#inclu ent:
<continues>

root@rock:~/Able2# blkcat -o 10260 able2.dd 5184 > 5184.blkcat

root@rock:~/Able2# ls -lh
total 474M
-rw-r--r-- 1 root root 1.0K 2008-11-27 04:19 5184.blkcat
-rw-r--r-- 1 root root 9.3M 2008-11-27 03:58 able2.blkls
-rwxrwxr-x 1 root root 330M 2003-08-10 21:16 able2.dd*
```

Note the size of the file resulting from the **blkcat** output (*5184.blkcat*) is 1.0k (1024 bytes – the file system block size), just as expected.

If we want to recover the actual file and meta data associated with the identified data block, we use **ifind** to determine which meta data structure (in this case *inode* since we are working on an EXT file system) holds the data in block 5184. Then **istat** shows us the meta data for the inode:

```
root@rock:~/Able2# ifind -o 10260 -d 5184 able2.dd
10090

root@rock:~/Able2# istat -o 10260 able2.dd 10090
inode: 10090
Not Allocated
Group: 5
Generation Id: 3534950782
uid / gid: 4 / 7
mode: -rw-r--r--
size: 3591
num of links: 0

Inode Times:
Accessed:    Sun Aug 10 00:18:36 2003
File Modified:    Wed Dec 25 16:27:43 1996
Inode Modified:   Sun Aug 10 00:29:58 2003
Deleted:     Sun Aug 10 00:29:58 2003

Direct Blocks:
5184 5185 5186 5187
```

Again, as we saw previously, the **istat** command, which shows us the meta data for inode 10090, indicates that the file with this inode is *Not Allocated*, and its first direct block is 5184. Just as we expected.

We then use **icat** to recover the file. In this case, we just pipe the first few lines out to see our string of interest, "*cybernetik*".

```
root@rock:~/Able2# icat -o 10260 able2.dd 10090 | head -n 10
/*
 *    fixer.c
 *    by Idefix
 *    inspired on sum.c and SaintStat 2.0
 *    updated by Cybernetik for linux rootkit
 */

#include <sys/types.h>
#include <sys/stat.h>
#include <sys/time.h>
<continues>
```

Sleuthkit Exercise #4 – NTFS Examination: File Analysis

At this point we've done a couple of intermediate exercises using an ext2 file system from a Linux disk image. Another common suggestion I receive in class feedback and from other users of this guide is to provide a more advanced exercise using a file system more commonly encountered by examiners in the field. So, in the following exercises we will do some simple analyses on an NTFS file system.

Some might ask, “why?” There are many tools out there capable of analyzing an NTFS file system in its native environment. In my mind there are two very good reasons for learning to apply the Sleuthkit on Windows file systems. First, the Sleuthkit is comprised of a number of separate tools with very discrete sets of capabilities. The specialized nature of these tools means that you have to understand their interaction with the file system being analyzed. This makes them especially suited to help learning the ins and outs of file system behavior. The fact that the Sleuthkit does *less* of the work for you makes it a great learning tool. Second, an open source tool that operates in an environment other than Windows makes for an excellent cross-verification utility.

The following exercise follows a set of very basic steps useful in most any analysis. Make sure that you follow along at the command line. Experimentation is the best way to learn.

If you have not already done so, I would strongly suggest (again) that you invest in a copy of Brian Carrier's book: File System Forensic Analysis (Published by Addison-Wesley, 2005). This book is the definitive guide to file system behavior for forensic analysts. As a reminder (again), the purpose of these exercises in NOT to teach you file systems (or forensic methods, for that matter), but rather to illustrate the detailed information Sleuthkit can provide on common file systems encountered by field examiners.

The file we will use for this exercise can be obtained from:

http://www.LinuxLEO.com/Files/ntfs_pract.dd.gz

Let's create a directory in our */root* (the root user's home) directory called */root/ntfs_pract/* and place the file in there. First, we will decompress the gzipped file using the **gzip** command we learned earlier and check its SHA1 hash:

```
root@rock:~/ntfs_pract # ls
ntfs_pract.dd.gz
root@rock:~/ntfs_pract # gzip -d ntfs_pract.dd.gz
root@rock:~/ntfs_pract # ls
ntfs_pract.dd
root@rock:~/ntfs_pract # sha1sum ntfs_pract.dd
0cbce7666c8db70377cb5fc2abf9268821b6dafe  ntfs_pract.dd
```

Now we will run through a series of basic Sleuthkit commands as we would in any analysis. The structure of the forensic image is viewed using **mmls**:

```
root@rock:~/ntfs_pract # mmls ntfs_pract.dd
DOS Partition Table
Offset Sector: 0
Units are in 512-byte sectors

     Slot    Start        End          Length       Description
00:  -----   0000000000   0000000000   0000000001   Primary Table (#0)
01:  -----   0000000001   0000000058   0000000058   Unallocated
02:  00:00   0000000059   0001023059   0001023001   NTFS (0x07)
03:  -----   0001023060   0001023999   0000000940   Unallocated
```

The output shows that an NTFS partition (and most likely the file system) begins at sector offset **59**. This is the offset we will use in all our Sleuthkit commands. We now use **fsstat** to have a look at the file system statistics inside that partition:

```
root@rock:~/ntfs_pract # fsstat -o 59 -f ntfs ntfs_pract.dd
FILE SYSTEM INFORMATION
--------------------------------------------
File System Type: NTFS
Volume Serial Number: E4D06402D063D8F6
OEM Name: NTFS
Volume Name: NEW VOLUME
Version: Windows XP

METADATA INFORMATION
--------------------------------------------
First Cluster of MFT: 42625
First Cluster of MFT Mirror: 63937
Size of MFT Entries: 1024 bytes
Size of Index Records: 4096 bytes
Range: 0 - 144
Root Directory: 5

CONTENT INFORMATION
--------------------------------------------
Sector Size: 512
Cluster Size: 4096
<continues>
```

Looking at the **fsstat** output on our NTFS file system, we see it differs greatly from the output we saw running on a Linux EXT file system. The tool is designed to provide pertinent information based on the file system being targeted. Notice that when run on an NTFS file system, **fsstat** provides us with information specific to NTFS, including data about the Master File Table (MFT) and specific attribute values.

We will now have a look at how the Sleuthkit interacts with active and deleted files on an NTFS file system, given the structure of MFT entries.

Let's begin this exercise with the output of **fls**. We can specify that **fls** *only* show us only "deleted" content on the command line with the **-d** option. We will use **-F** (only file entries) and **-r** (recursive) as well:

```
root@rock:~/ntfs_pract # fls -Frd -o 59 ntfs_pract.dd
r/r * 42-128-1: Cookies/buckyball@revsci[2].txt
r/r * 43-128-1: Cookies/buckyball@search.msn[1].txt
r/r * 44-128-1: Cookies/buckyball@slashdot[1].txt
r/r * 45-128-1: Cookies/buckyball@sony.aol[2].txt
r/r * 112-128-4:        My Documents/My Pictures/bandit-streetortrack2005056.jpg
r/r * 116-128-4:        My Documents/My Pictures/fighterama2005-ban4.jpg
r/r * 81-128-4: My Documents/direct_attacks.doc
```

As of Sleuthkit version 3, the output of **fls** now shows content that includes NTFS "orphan" files.[20] Previous versions required the user to run an additional command, **ifind,** on parent directories in order to recover orphan files. The article in the footnote explains how this works.

The output above shows that our NTFS example file system holds 7 deleted files. Let's have a closer look at some NTFS specific information that can be parsed with the Sleuthkit.

Have a look a the deleted file at MFT entry *112*. The file is *./My Documents/My Pictures/bandit-streetortrack2005056.jpg*. We can have a closer look at the file's attributes by examining its MFT entry directly. We do this through the **istat** tool. Recall that when we were working on an EXT file system previously, the output of **istat** gave us information directly from the *inode* of the specified file (see Sleuthkit Exercise #1). As we mentioned earlier, the output of the Sleuthkit tools is specific to the file system being examined. So let's run the command on MFT entry *112* in our current exercise:

[20]TSK Informer, issue #16: http://www.sleuthkit.org/informer/sleuthkit-informer-16.txt "NTFS Orphan Files"

```
root@rock:~/ntfs_pract # istat -o 59 ntfs_pract.dd 112
MFT Entry Header Values:
Entry: 112        Sequence: 2
$LogFile Sequence Number: 4201668
Not Allocated File
Links: 2

$STANDARD_INFORMATION Attribute Values:
Flags: Archive
Owner ID: 0
Created:    Sat Apr  7 00:52:53 2007
File Modified:    Sat Oct 14 10:37:13 2006
MFT Modified:     Sat Apr  7 00:52:53 2007
Accessed:   Sat Apr  7 20:00:04 2007

$FILE_NAME Attribute Values:
Flags: Archive
Name: bandit-streetortrack2005056.jpg
Parent MFT Entry: 110   Sequence: 1
Allocated Size: 0       Actual Size: 0
Created:    Sat Apr  7 00:52:53 2007
File Modified:    Sat Apr  7 00:52:53 2007
MFT Modified:     Sat Apr  7 00:52:53 2007
Accessed:   Sat Apr  7 00:52:53 2007

Attributes:
Type: $STANDARD_INFORMATION (16-0)   Name: N/A   Resident   size: 72
Type: $FILE_NAME (48-3)   Name: N/A   Resident   size: 90
Type: $FILE_NAME (48-2)   Name: N/A   Resident   size: 128
Type: $DATA (128-4)   Name: $Data   Non-Resident   size: 112063
60533 60534 60535 60536 60537 60538 60539 60540
60541 60542 60543 60544 60545 60546 60547 60548
60549 60550 60551 60552 60553 60554 60555 60556
60557 60558 60559 60560
```

The information **istat** provides us from the MFT shows values directly from the *$STANDARD_INFORMATION* attribute (which contains the basic meta data for a file), the *$FILE_NAME* attribute and basic information for other attributes that are part of an MFT entry. The data blocks that contain the actual file content are listed at the bottom of the output (for Non-Resident data).

Take note of the fact that there are two separate attribute identifiers for the *$FILE_NAME* attribute, *48-3* and *48-2*. It is interesting to note we can access the contents of each attribute separately using the **icat** command.

The two attributes store the DOS (8.3) filename and the Win32 (long) file name. By piping the output of **icat** to **xxd** we can see the difference. By itself, this may not be of much investigative interest, but again we are illustrating the capabilities of the Sleuthkit tools.

Note the difference in output between the attribute identifiers *112-48-3* and *112-48-2*:

```
root@rock:~/ntfs_pract # icat -o 59 ntfs_pract.dd 112-48-3 | xxd
0000000: 6e00 0000 0000 0100 3071 be99 d078 c701  n.......0q...x..
0000010: 3071 be99 d078 c701 3071 be99 d078 c701  0q...x..0q...x..
0000020: 3071 be99 d078 c701 0000 0000 0000 0000  0q...x..........
0000030: 0000 0000 0000 0000 2000 0000 0000 0000  ........ .......
0000040: 0c02 4200 4100 4e00 4400 4900 5400 7e00  ..B.A.N.D.I.T.~.
0000050: 3100 2e00 4a00 5000 4700                 1...J.P.G.
```

```
root@rock:~/ntfs_pract # icat -o 59 ntfs_pract.dd 112-48-2 | xxd
0000000: 6e00 0000 0000 0100 3071 be99 d078 c701  n.......0q...x..
0000010: 3071 be99 d078 c701 3071 be99 d078 c701  0q...x..0q...x..
0000020: 3071 be99 d078 c701 0000 0000 0000 0000  0q...x..........
0000030: 0000 0000 0000 0000 2000 0000 0000 0000  ........ .......
0000040: 1f01 6200 6100 6e00 6400 6900 7400 2d00  ..b.a.n.d.i.t.-.
0000050: 7300 7400 7200 6500 6500 7400 6f00 7200  s.t.r.e.e.t.o.r.
0000060: 7400 7200 6100 6300 6b00 3200 3000 3000  t.r.a.c.k.2.0.0.
0000070: 3500 3000 3500 3600 2e00 6a00 7000 6700  5.0.5.6...j.p.g.
```

The same idea is extended to other attributes of a file, most notably the "Alternate Data Streams" or ADS. By showing us the existence of multiple attribute identifiers for a given file, the Sleuthkit gives us a way of detecting potentially hidden data. We cover this in our next exercise.

Sleuthkit Exercise #5 – NTFS Examination: ADS

First, to see what we are discussing here, in case the reader is not familiar with alternate data streams, we should compare the output of a normal file listing with that obtained through a forensic utility.

Obviously, when examining a system, it may be useful to get a look at all of the files contained in an image. We can do this two ways. The first way would be to simply mount our image with the loop back device and get a file listing. We will do this to compare a method using standard command line utilities that we used in the past with a method using the Sleuthkit tools.

Remember that the **mount** command works on file systems, not disks. The file system in this image starts 59 sectors into the image, so we mount using an offset. We can then obtain a simple list of files using the **find** command:

```
root@rock:~/ntfs_pract # mount -t ntfs -o ro,loop,offset=30208
                        ntfs_pract.dd /mnt/analysis/
root@rock:~/ntfs_pract # cd /mnt/analysis/
root@rock:~/analysis # find . -type f
./Cookies/buckyball@as-eu.falkag[2].txt
./Cookies/buckyball@2o7[1].txt
./Cookies/buckyball@ad.yieldmanager[1].txt
./Cookies/buckyball@specificclick[1].txt
./Cookies/buckyball@store.makezine[1].txt
./Cookies/buckyball@store.yahoo[2].txt
... [content removed]
./Favorites/2600 The Hacker Quarterly.url
... [content removed]
./My Documents/My Pictures/Tails/GemoTailG4.jpg
./My Documents/signatures.pdf
./My Documents/ULTIMATEJOURNEYDK.wmv
./My Documents/Webstuff/bandit2.jpg
./My Documents/Webstuff/m2_flat_CF.jpg
./My Documents/Webstuff/service1.jpg
./My Documents/Webstuff/Thumbs.db
./NTUSER.DAT
./SVstunts.avi                    <---Take note of this file
```

We **mount** the image with an offset of **30208** (59*512) to access the NTFS file system. We then change to the directory containing our mounted image and run our **find** command, starting in the current directory ("**.**"), looking for all regular files (**type -f**). The result gives us a list of all the allocated *regular* files on the mount point. Of particular interest in this output is the last file in the list, *SVstunts.avi*. Take note of this file. Our current method of listing files, however, gives us no indication of why this file is noteworthy.

The output of the **file** commands shows us the expected output. It is an avi video. Were we to install a video player and the proper codecs, we would see that it is, in fact, a normal video[21].

```
root@rock:~/ntfs_pract # file /mnt/analysis/SVstunts.avi
/mnt/tmp/SVstunts.avi: RIFF (little-endian) data, AVI, 160 x 120,
15.00 fps, video: Cinepak
```

Now let's try another method of obtaining a file list. Since this is a forensic examination, let's use a forensic tool to give us a list of files. We will use the **fls** command with the **-F** option to show only files, and the **-r** option to recurse through directories (starting from the root directory, by default). The "..." signifies removed output for brevity.

```
root@rock:~/ntfs_pract # fls -Fr -o 59 -f ntfs ntfs_pract.dd
r/r 4-128-4:    $AttrDef
r/r 8-128-2:    $BadClus
r/r 8-128-1:    $BadClus:$Bad
r/r 6-128-1:    $Bitmap
...
r/r 0-128-1:    $MFT
r/r 1-128-1:    $MFTMirr
r/r 9-128-8:    $Secure:$SDS
...
r/r * 42-128-1: Cookies/buckyball@revsci[2].txt
r/r * 43-128-1: Cookies/buckyball@search.msn[1].txt
r/r * 44-128-1: Cookies/buckyball@slashdot[1].txt
...
r/r 128-128-3:    My Documents/My Pictures/Thumbs.db
r/r 128-128-4:    My Documents/My Pictures/Thumbs.db:encryptable
r/r * 112-128-4:  My Documents/My Pictures/bandit-
streetortrack2005056.jpg
r/r * 116-128-4:  My Documents/My Pictures/fighterama2005-ban4.jpg
r/r 129-128-4:    My Documents/Osuny Articles courtesy of BIOC Agent.doc
r/r 130-128-4:    My Documents/signatures.pdf
r/r 131-128-4:    My Documents/ULTIMATEJOURNEYDK.wmv
r/r 133-128-3:    My Documents/Webstuff/bandit2.jpg
r/r 134-128-4:    My Documents/Webstuff/m2_flat_CF.jpg
r/r 135-128-3:    My Documents/Webstuff/service1.jpg
r/r 136-128-3:    My Documents/Webstuff/Thumbs.db
r/r * 81-128-4:   My Documents/direct_attacks.doc
r/r 138-128-3:    NTUSER.DAT
r/r 137-128-3:  SVstunts.avi                 <---Using fls we now see
r/r 137-128-4:  SVstunts.avi:hacktrap.txt        two entries for this file
```

[21]You can use the **xine** player on a standard Slackware intallation.

Note that **fls** displays far more information for us than our **find** command on the mounted file system. Included with our "regular files" are the NTFS system files (starting with the "$"), including the *$MFT* and *$MFTMIRROR* (record numbers 0 and 1). Also note the last file in the list again, *SVstunts.avi.* In the output of **fls**, *SVstunts.avi* has two entries:

```
r/r 137-128-3:  SVstunts.avi
r/r 137-128-4:  SVstunts.avi:hacktrap.txt
```

Both entries have the same MFT record number and are identified as file data (137-128) but the attribute identifier increments by one (137-128-3 and 137-128-4)[22]. This is an example of an "Alternate Data Stream" (ADS). Accessing the standard contents (137-128-3) of *SVstunts.avi* is easy, since it is an allocated file. However, we can access either data stream, the normal data or the ADS, by using the Sleuthkit command **icat**, much as we did with the two file name types in our previous exercise. We simply call **icat** with the complete MFT record entry, to include the alternate attribute identifier. To view the contents of the ADS (137-128-4):

```
root@rock:~/ntfs_pract # icat -o 59 -f ntfs ntfs_pract.dd 137-128-4

   <()>-<()>-<()>-<()>-<()>-<()>-<()>-<()>-<()>-<()>-<()>-<()>-<()>
   /||                                                          ||\
   \||         P R O F E S S O R   F A L K E N ' S              ||/
   /||                                                          ||\
   \||                     GUIDE TO                             ||/
   /||                                                          ||\
   \||            *****  *****  ****   *****                    ||/
   /||            *   *  *   *  *   *  *                        ||\
   \||            *      *   *  *   *  *****                    ||/
   /||            *   *  *   *  *   *  *                        ||\
   \||            *****  *****  ****   *****                    ||/
   /||                                   P {                    ||\
   \||                                                          ||/
   /||                 HACKING  SECURITY                        ||\
   \||                                                   (C)1988||/
   <()>-<()>-<()>-<()>-<()>-<()>-<()>-<()>-<()>-<()>-<()>-<()>-<()>


   First I'd like to thank the following people for thier contributions

<continues>
```

Pipe the results through **less** to see the whole file, or redirect the output to another file.

[22] Again, I would urge you to read Carrier's book: File System Forensic Analysis.

Sleuthkit Exercise #6 – NTFS Examination: Sorting Files

We will now explore a Sleuthkit tool we have not looked at yet. Many forensic tools provide a mechanism for categorizing files based on type. This reduces the amount of time examiners need to spend finding files of interest. The Sleuthkit provides this function through the **sorter** command. This tool parses the allocated and unallocated files of a file system and tests their headers for file type (remember the **file** command from our earlier exercise?).

The **sorter** command is highly configurable. The default files are found in the *./share/sorter* directory of the Sleuthkit installation. The file *default.sort* is used for all operating systems, and there are also configuration files specific to each operating system.

There are a number of ways **sorter** can report its findings. It is useful to have the categories of files written out to a directory specified by the analyst. First we need to create a directory to write these results to:

```
root@rock:~/ntfs_pract # mkdir sort_out
```

Let's run the command and have a look at the output. There are lots of options available for sorter. Here's the command we'll use:

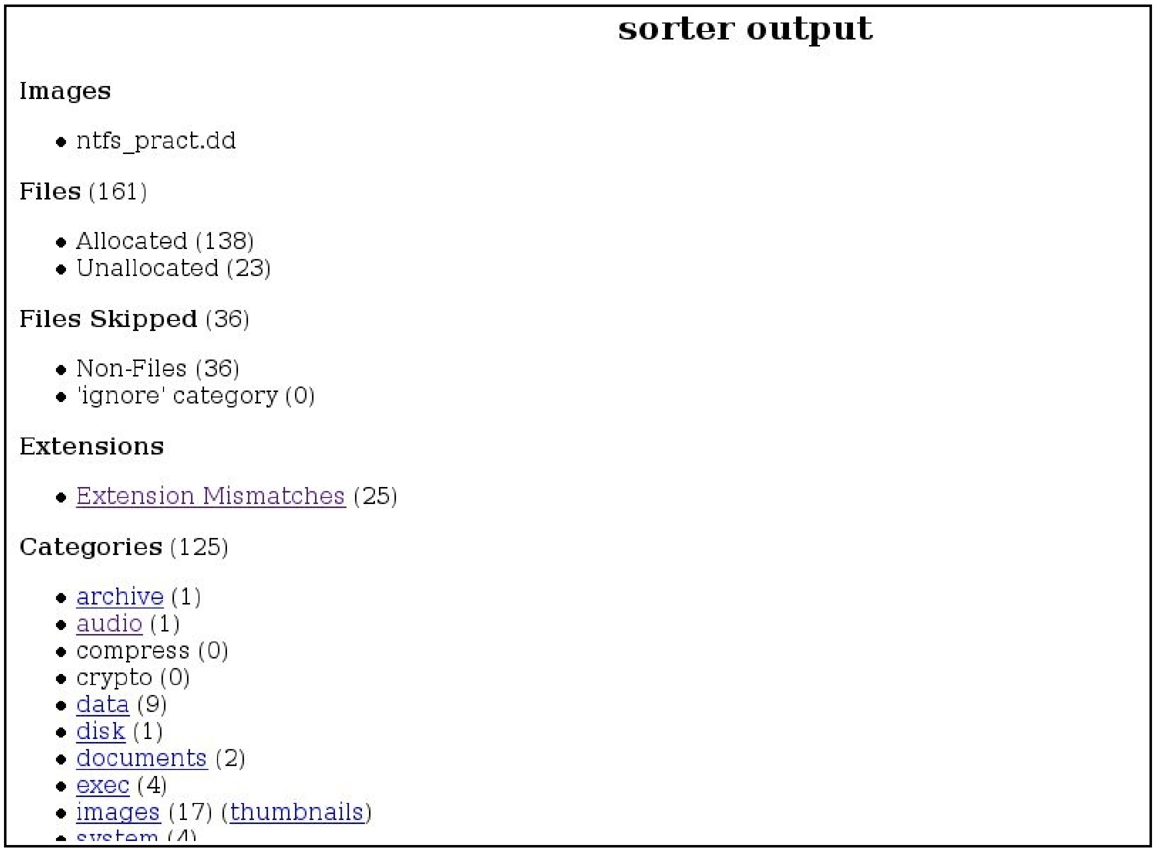
```
root@rock:~/ntfs_pract # sorter -d ./sort_out -md5 -h -s -o 59 -f ntfs ntfs_pract.dd
Analyzing  "ntfs_pract.dd"
  Loading Allocated File Listing
  Processing 138 Allocated Files and Directories
  100%

  Loading Unallocated File Listing
  Processing 23 Unallocated meta-data structures
  100%

All files have been saved to: ./sort_out
```

We call the **sorter** command with the **-d <output directory>** option to write our results and categorize the files. The **-md5** option hashes the files for us. We use the **-h** option to create html output rather than the default text files. The **-s** option copies the categorized files to the output directory and the other options are the standard Sleuthkit options required to specify the file system.

Our output ends up in the *./sort_out* directory:

```
root@rock:~/ntfs_pract # ls sort_out/
archive/       audio.html  disk/       documents.html  images/       mismatch.html
archive.html   data/       disk.html   exec/           images.html   system/
audio/         data.html   documents/  exec.html       index.html    system.html
text.html      text/       unknown.html
```

Note that we have an *index.html file*. This can be opened in our Web browser of choice. We also have a set of directories containing our files (exported with the **-s** option) and html pages for each. The index page, generated from our above **sorter** command, looks like this:


sorter output

Images

- ntfs_pract.dd

Files (161)

- Allocated (138)
- Unallocated (23)

Files Skipped (36)

- Non-Files (36)
- 'ignore' category (0)

Extensions

- Extension Mismatches (25)

Categories (125)

- archive (1)
- audio (1)
- compress (0)
- crypto (0)
- data (9)
- disk (1)
- documents (2)
- exec (4)
- images (17) (thumbnails)
- system (4)

The page is basic html and easy to edit for your report. The name of the image used as input is given along with basic information about the numbers of allocated and unallocated files processed. Note that we are also given the number of, and a link to, "Extension Mismatches" - where the file header information identified a file different than the extension on the file name.

If you look down the list of categories, you will see “images”. The sorter command found 17 images (pictures). You can click on the “images” link and see information for each file found, including a link to the exported image:

images Category

My Documents/My Pictures/b45ac806a965017dd71e3382581c47f3_refined.jpg
  JPEG image data, JFIF standard 1.01
  Image: ntfs_pract.dd Inode: 111-128-4
  MD5: 2c966ade4ff16ef8fe95e6607987644e
  Saved to: images/ntfs_pract.dd-111-128-4.jpg

`<continues>`

Or you can click on “thumbnails” to view the pictures together:

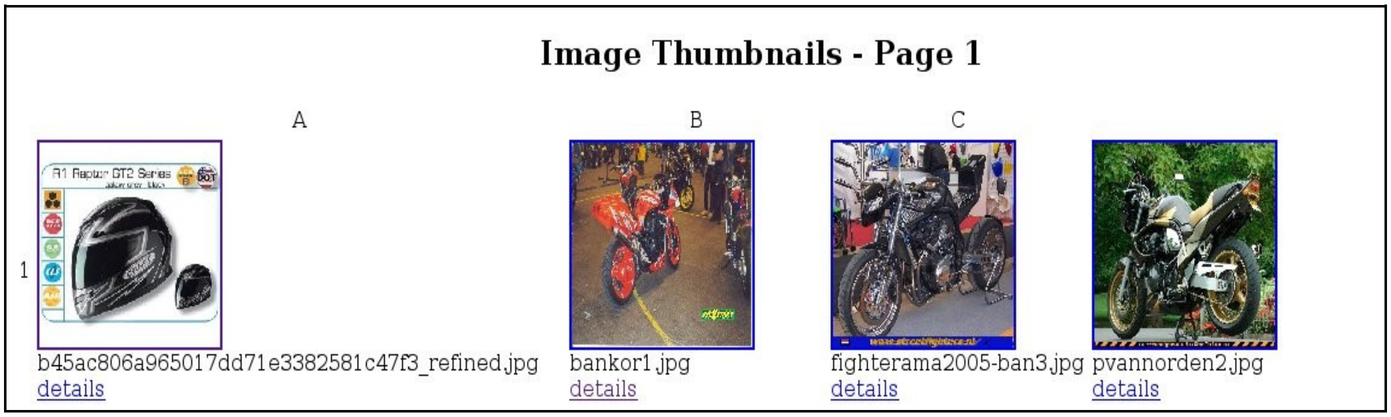


Image Thumbnails - Page 1

	A	B	C	
1	b45ac806a965017dd71e3382581c47f3_refined.jpg details	bankor1.jpg details	fighterama2005-ban3.jpg details	pvannorden2.jpg details

As we can see, **sorter** provides a very convenient way to organize files based on type. This is a powerful tool with fully customizable configuration files where you can limit what is categorized and processed. Read the **man** pages. There are options available in sorter to utilize hash databases for further data reduction and other useful features.

What we have seen here are simple (and in many ways incomplete) examples of the Sleuthkit’s command line tools for forensic examination. If you are left a little confused, just go through the exercises and steps one at a time. If you don’t understand the commands or options, check the usage and read the **man** pages and Sleuthkit documentation. Run through the exercise a couple of times, and the purpose and outcome will make more sense. Take your time and experiment a little with the options.

Sleuthkit Exercise #7 – Signature Search in Unallocated Space

Now let's do the same sort of unallocated analysis we did in Exercise #3, but this time instead of searching for text data, we will look for file signatures. This will give us an opportunity to introduce another useful Sleuthkit tool, **sigfind**.

For this particular exercise, we'll use the NTFS image we used previously, *ntfs_pract.dd*. Change to the directory containing that image and let's begin.

As always, we start with **mmls** to help us identify the offset of the file system within the image that we are interested in.

```
root@rock:~/NTFS# mmls ntfs_pract.dd
DOS Partition Table
Offset Sector: 0
Units are in 512-byte sectors

     Slot    Start        End          Length       Description
00:  -----   0000000000   0000000000   0000000001   Primary Table (#0)
01:  -----   0000000001   0000000058   0000000058   Unallocated
02:  00:00   0000000059   0001023059   0001023001   NTFS (0x07)
03:  -----   0001023060   0001023999   0000000940   Unallocated
```

Here we want to study the unallocated data from the NTFS file system at sector offset *59*. So we issue our **blkls** command and redirect the output to another file:

```
root@rock:~/NTFS# blkls -o 59 ntfs_pract.dd > ntfs_pract.blkls

root@rock:~/NTFS# ls -lh
total 995M
-rw-r--r-- 1 root    root  478M 2008-06-09 10:01 ntfs_pract.blkls
```

Once again, the output file is arbitrarily named. I give it a *.blkls* extension for the sake of simplicity. Now, let's go ahead and search the unallocated image we created for JPEG images. We use these JPEG picture files for our example because most experienced forensic examiners are familiar with the signatures.

To do this search, we could use the string “JFIF”, a known component of JPEG file signatures. Using **xxd** to give us an ASCII representation of the file, we could simply search using **grep** for the characters “JFIF”, take note of the offsets and work from there, much like we did in our *Data carving with dd* exercise. In that case, though, we looked for the *ffd8* hex signature. We then had to do a number of calculations to covert the **xxd** hex values, etc. Refer back to the *Data carving with dd* exercise for more info and a refresher on how we did this.

There are issues with using **grep** to search for data in a forensic image or file system. Aside from having to rely on values and conversions from **xxd** (which gives us our ASCII representation for **grep**), another problem with using **grep** is that it is completely unaware of sector or data block boundaries. The **grep** program is actually designed to search for text in files, not signatures in forensic images or file systems. Depending on the system being employed, there may also be file size (addressing) limitations with using **grep** on large images.

So instead, let's have a look at a far more forensic friendly signature search tool provided by the Sleuthkit. This tool, **sigfind** is designed to look for hex signatures with search block sizes specified by the user and offsets to the signature within that block size.

sigfind is most commonly used to search for signatures of disk structures, and is particularly well suited to this task, because in addition to showing each hit, it shows the distance from the previous hit. This is helpful in that it allows a knowledgeable examiner to determine the veracity of hits by the expected frequency and distance between certain file system structures (like EXT superblocks, for example). In fact, **sigfind** works with a number of *templates* that are supported by the **-t** option. Run the command with **-t** to see a list of included templates.

As we mentioned, a file system's block size can be passed to **sigfind** so that each block can be searched for the proper expression at a given offset, which helps account for cluster aligned files or structures[23]. We already determined the cluster size in the *ntfs_pract.dd* NTFS file system is 4096 (found using **fsstat**). It is important for a Sleuthkit beginner to realize that the offset we provide to the **sigfind** command is different from the offset we provide in other Sleuthkit commands. In most Sleuthkit commands that are passed an offset option with **-o** we are referring to the location (offset in sectors) of a file system within a forensic image. It the case of **sigfind** the offset we pass with **-o** is the offset to the specified signature from the start of each block being searched as specified by block size (**-b**).

[23]But will not help with files embedded within other files, of course.

For example, the **man** page for **sigfind** gives the example of searching for a boot sector signature with the command:

```
root@rock:~/NTFS# sigfind -o 510 -l AA55 disk.dd
```

In this case, the block size is the default *512* (no **-b** option is given). The **-o 510** tells **sigfind** to look for the signature 510 bytes into every sector it searches. The **-l** option refers to the endian ordering of the signature.

Back to our exercise at hand...We must also keep in mind that **sigfind** takes *hex* as it's signature string, so unlike **grep**, we cannot simply search for “JFIF”. We need to convert the ASCII string to hex. This is easily done by echoing the string to **xxd** with the **-p** option (continuous or “plain” dump):

```
root@rock:~/NTFS# echo -n JFIF | xxd -p
4a464946
```

Also note in the above command, we use the **-n** option to **echo** to prevent a newline character from being passed to **xxd** as well. The hex signature we are going to search for is **4A464946** (“JFIF”).

We can now do our **sigfind** command.

```
root@rock:~/NTFS# sigfind -b 4096 -o 6 4A464946 ntfs_pract.blkls
Block size: 4096  Offset: 6  Signature: 4A464946
Block: 57539 (-)
Block: 57582 (+43)
```

The command above shows us running **sigfind** with a block size (**-b**) of **4096** (from **fsstat** output), an offset (**-o**) of **6**, and a signature of **4A464946** on the extracted unallocated space **ntfs_pract.blkls**.

As you can see, we come up with two hits. Now we use the **blkcalc** command to determine the block address of the unallocated block in the original image.

```
root@rock:~/NTFS# blkcalc -o 59 -u 57539 ntfs_pract.dd
60533
```

Above, we called **blkcalc** with **-u 57539** to indicate that we are passing an address from an unallocated image provided by **blkls**. The file system this unallocated block was extracted from is in our *ntfs_pract.dd* image at sector offset **59**. The result shows us that unallocated block **57539** in our **blkls** image maps to data block **60533** in the original file system.

Now that we have the data block (**60533**) in the original file system, we can use **ifind** to identify the meta data structure that is assigned to that data block. In this case the meta data structure is an MFT entry, since we are working with an NTFS file system.

```
root@rock:~/NTFS# ifind -o 59 -d 60533 ntfs_pract.dd
112-128-4
```

The MFT entry is *112-128-4* or simply *112* (The *128-4* portion denotes the *$DATA* attribute identifier). We can use **ffind** to determine the file name that holds (or held) that particular MFT entry. Be very careful of interpretation here. As always, you need to have a firm grip on how the file system works before deciding that the information being presented is accurate, depending on the file system being examined.

```
root@rock:~/NTFS# ffind -o 59 ntfs_pract.dd 112
* /My Documents/My Pictures/bandit-streetortrack2005056.jpg
```

Recovering the deleted file using **icat** and piping the results to the **file** command indicates that we have found a JPEG image, which the previous **ffind** command indicated may have been called *bandit-streetortrack2005056.jpg*.

```
root@rock:~/NTFS# icat -o 59 ntfs_pract.dd 112 | file -
/dev/stdin: JPEG image data, JFIF standard 1.02
```

Recall now our original **sigfind** output:

```
root@rock:~/NTFS# sigfind -b 4096 -o 6 4A464946 ntfs_pract.blkls
Block size: 4096  Offset: 6  Signature: 4A464946
Block: 57539 (-)
Block: 57582 (+43)
```

We have already recovered (or at least identified) the deleted file at unallocated block *57539* in our **blkls** image. Running those same commands on the second hit at *57582* will give us this:

```
root@rock:~/NTFS# blkcalc -u 57582 -o 59 ntfs_pract.dd
60662

root@rock:~/NTFS# ifind -o 59 -d 60662 ntfs_pract.dd
116-128-4

root@rock:~/NTFS# ffind -o 59 ntfs_pract.dd 116
* /My Documents/My Pictures/fighterama2005-ban4.jpg

root@rock:~/NTFS# icat -o 59 ntfs_pract.dd 116 | file -
/dev/stdin: JPEG image data, JFIF standard 1.01
```

We have another JPEG, this one at MFT entry *116*, and named *fighterama2005-ban4.jpg*.

We can actually recover both files by using **icat** and redirecting to new files. I've named the files by their MFT entry and the .jpg extension, since the **file** command confirmed that's what they are.

```
root@rock:~/NTFS# icat -o 59 ntfs_pract.dd 112 > 112.jpg
root@rock:~/NTFS# icat -o 59 ntfs_pract.dd 116 > 116.jpg
```

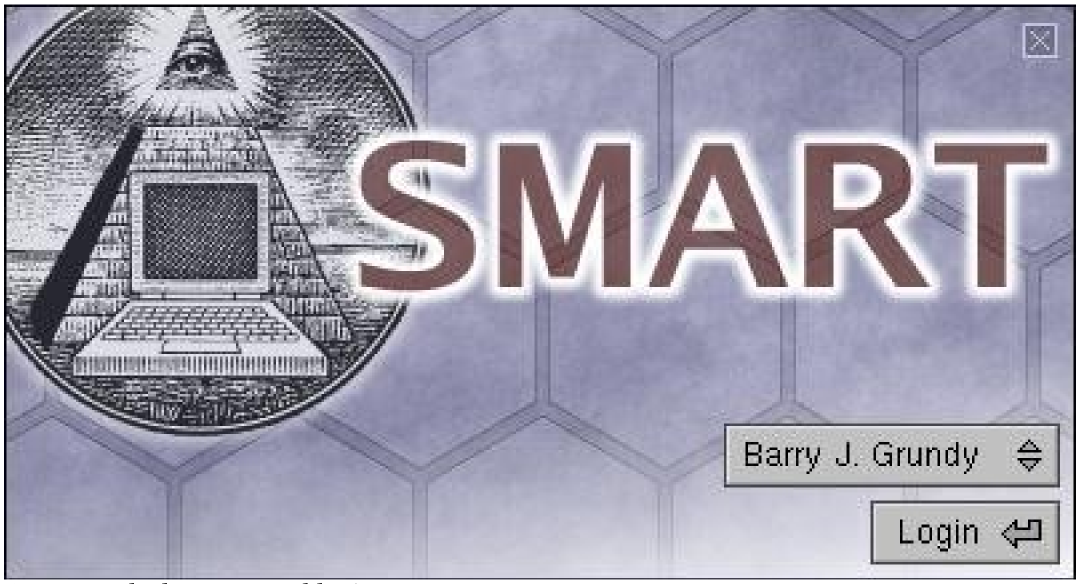
You can now view the files with any graphics viewer you might have available. For example, you can use the **display** command:

```
root@rock:~/NTFS# display 112.jpg
<shows image on desktop>
```

SMART for Linux

SMART, by ASR Data, is a commercial (not free) GUI based forensic tool for Linux that has a great interface allowing access to a full set of forensic analysis capabilities.

http://www.asrdata.com/SMART/



SMART splash screen and login.

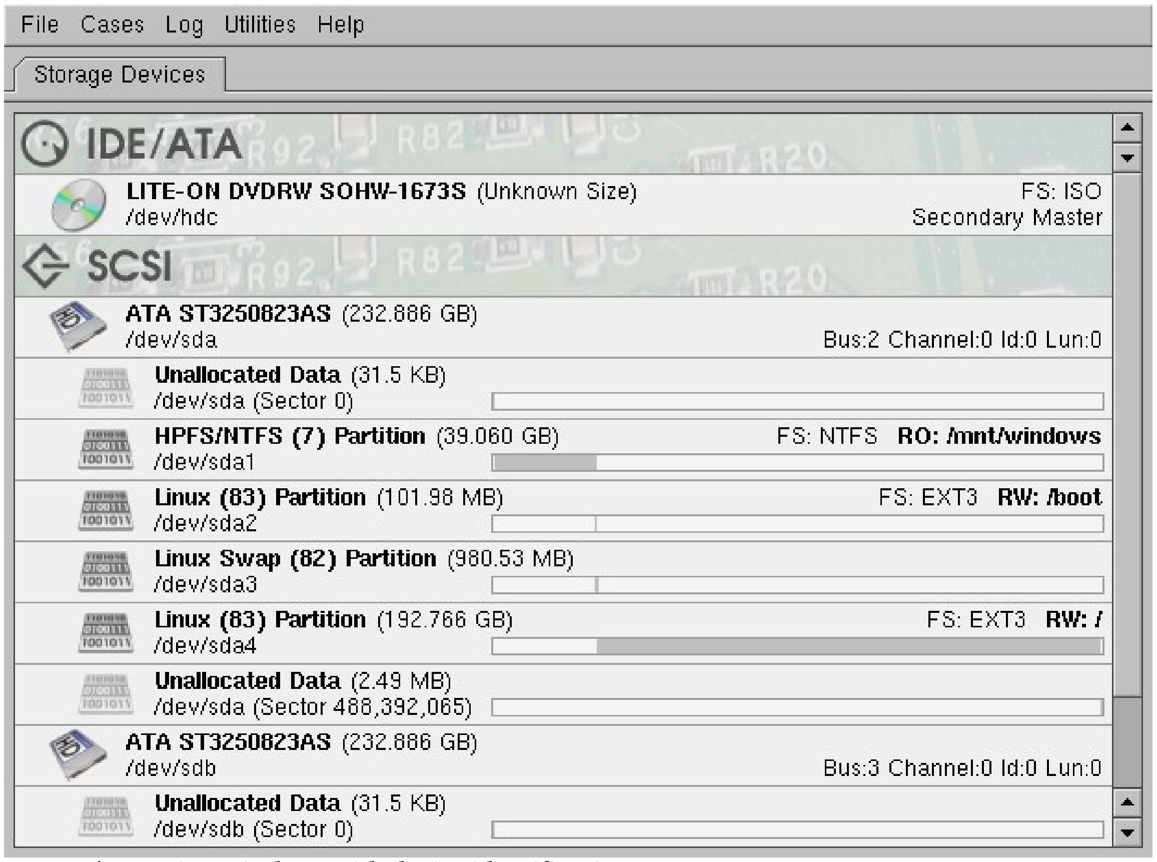
Following is a small tour to give you a taste of the SMART interface. The official user manual for SMART is packed with useful information, and this section is not meant to be an exhaustive manual. We are just providing a brief overview of some of SMART's major capabilities. If you would like to follow along, there is an evaluation version (no acquisition or export capability) of SMART available at:

http://www.asrdata2.com/[24]

The evaluation version also comes with the SMART manual in PDF format. A worthwhile read.

[24] The evaluation file is in "bz2" format. Untar with the "xjvf" switches, change to the resulting directory and read the INSTALL file.

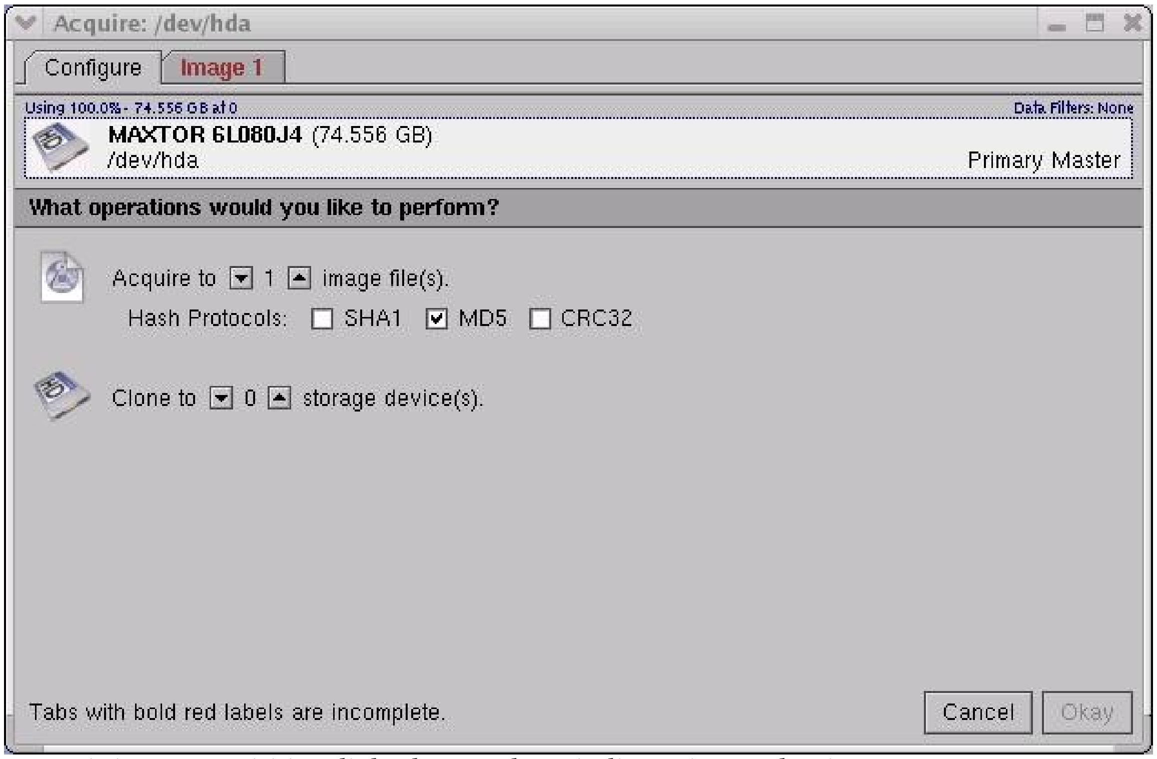
Opening SMART provides the user with a view of the physical layout of all the devices recognized on the system, including internal and external drives. This gives the examiner an overall picture of what file systems reside on each drive, the sizes of each partition, and the amount of unallocated space on the drive.



```
LITE-ON DVDRW SOHW-1673S (Unknown Size)                      FS: ISO
/dev/hdc                                            Secondary Master
ATA ST3250823AS (232.886 GB)
/dev/sda                                 Bus:2 Channel:0 Id:0 Lun:0
   Unallocated Data (31.5 KB)
   /dev/sda (Sector 0)
   HPFS/NTFS (7) Partition (39.060 GB)     FS: NTFS  RO: /mnt/windows
   /dev/sda1
   Linux (83) Partition (101.98 MB)              FS: EXT3  RW: /boot
   /dev/sda2
   Linux Swap (82) Partition (980.53 MB)
   /dev/sda3
   Linux (83) Partition (192.766 GB)                 FS: EXT3  RW: /
   /dev/sda4
   Unallocated Data (2.49 MB)
   /dev/sda (Sector 488,392,065)
ATA ST3250823AS (232.886 GB)
/dev/sdb                                 Bus:3 Channel:0 Id:0 Lun:0
   Unallocated Data (31.5 KB)
   /dev/sdb (Sector 0)
```

SMART's opening window, with device identification.

SMART is a “right click” driven program. Most functions available to an examiner for a given object are accessed through a mouse driven menu system. For instance, right clicking on a physical device (disk or partition) provides a menu that includes “Acquire”. Selection of this item provides a dialog box to allow forensic imaging.


Acquire: /dev/hda

Configure | Image 1

Using 100.0% - 74.556 GB at 0 Data Filters: None

MAXTOR 6L080J4 (74.556 GB)
/dev/hda Primary Master

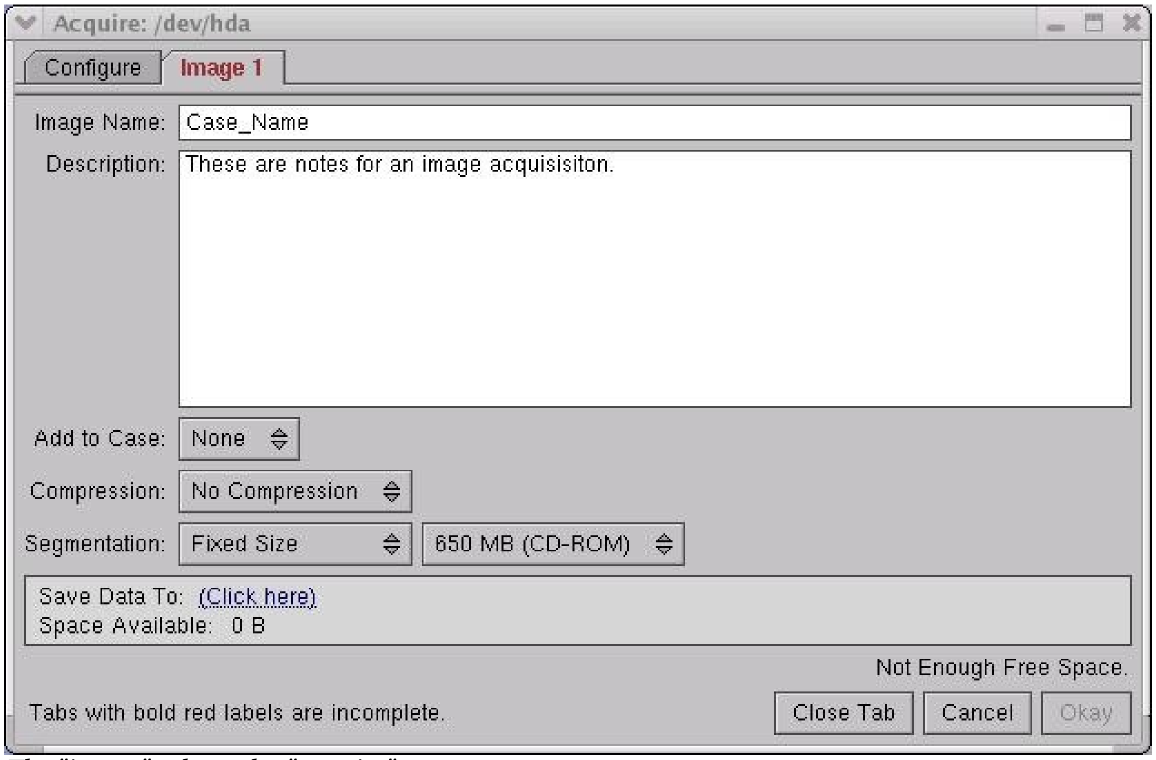
What operations would you like to perform?

Acquire to 1 image file(s).
Hash Protocols: ☐ SHA1 ☑ MD5 ☐ CRC32

Clone to 0 storage device(s).

Tabs with bold red labels are incomplete.

Forensic image acquisition dialog box. Red text indicates incomplete items...


Acquire: /dev/hda

Configure | Image 1

Image Name: Case_Name
Description: These are notes for an image acquisisiton.

Add to Case: None
Compression: No Compression
Segmentation: Fixed Size 650 MB (CD-ROM)

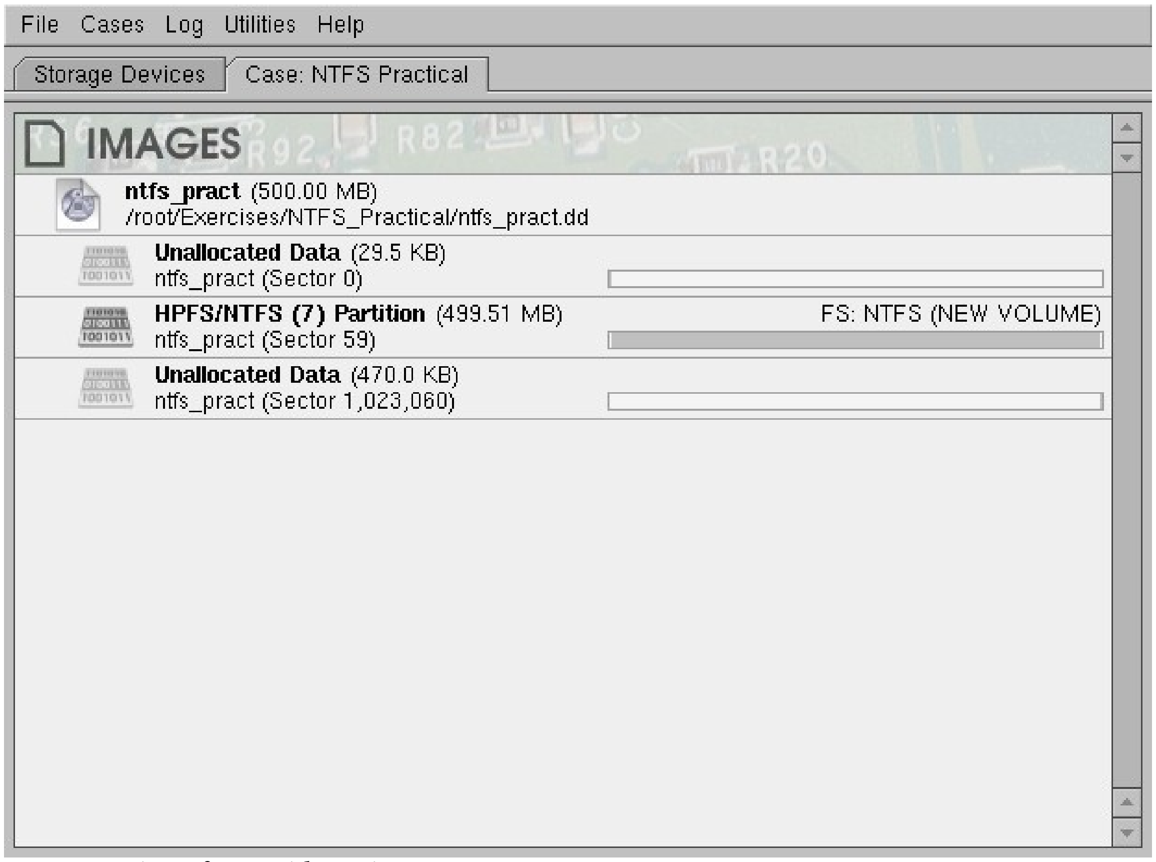
Save Data To: (Click here)
Space Available: 0 B

Not Enough Free Space.

Tabs with bold red labels are incomplete.

The "image" tab, under "acquire".

Case management under SMART is straightforward. Once a forensic image (or multiple images) is added as evidence to a case, SMART will parse the image and provide details on the contents. Here we've opened a new case called "NTFS Practical" and added our *ntfs_pract.dd* image to that case:



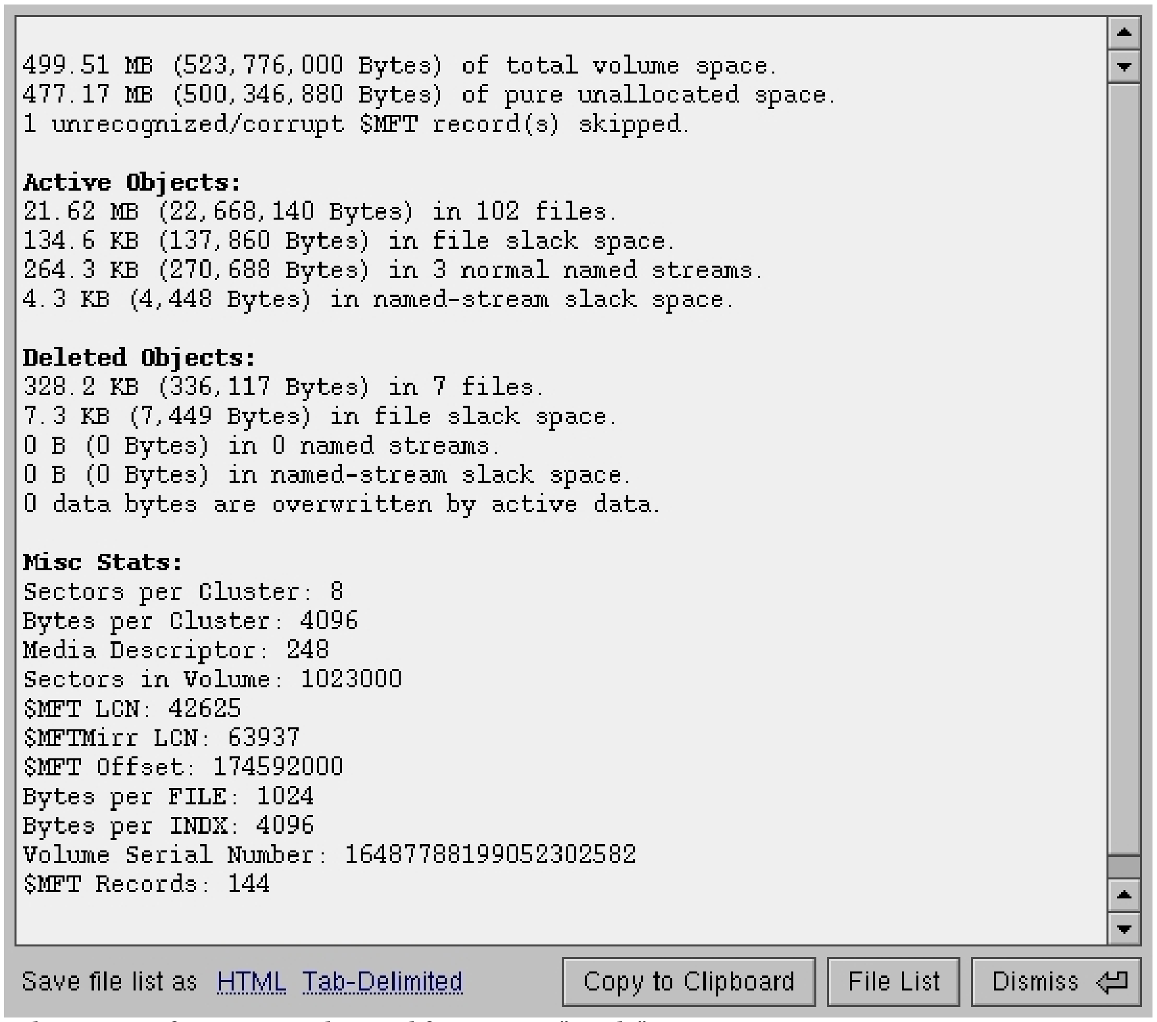
```
ntfs_pract (500.00 MB)
/root/Exercises/NTFS_Practical/ntfs_pract.dd
Unallocated Data (29.5 KB)
ntfs_pract (Sector 0)
HPFS/NTFS (7) Partition (499.51 MB)                FS: NTFS (NEW VOLUME)
ntfs_pract (Sector 59)
Unallocated Data (470.0 KB)
ntfs_pract (Sector 1,023,060)
```

A SMART view of our evidence image.

We see each of the partitions as a graphical representation of the same sort of information we might gather using **fdisk –l** or **mmls** on a physical disk.

Right clicking on a partition allows you to "Study" it and obtain information and a file listing (including deleted files).

In our NTFS example, we can right click on the NTFS partition at sector offset 59, select "*Filesystem --> SMART --> Study*" and obtain the following information:

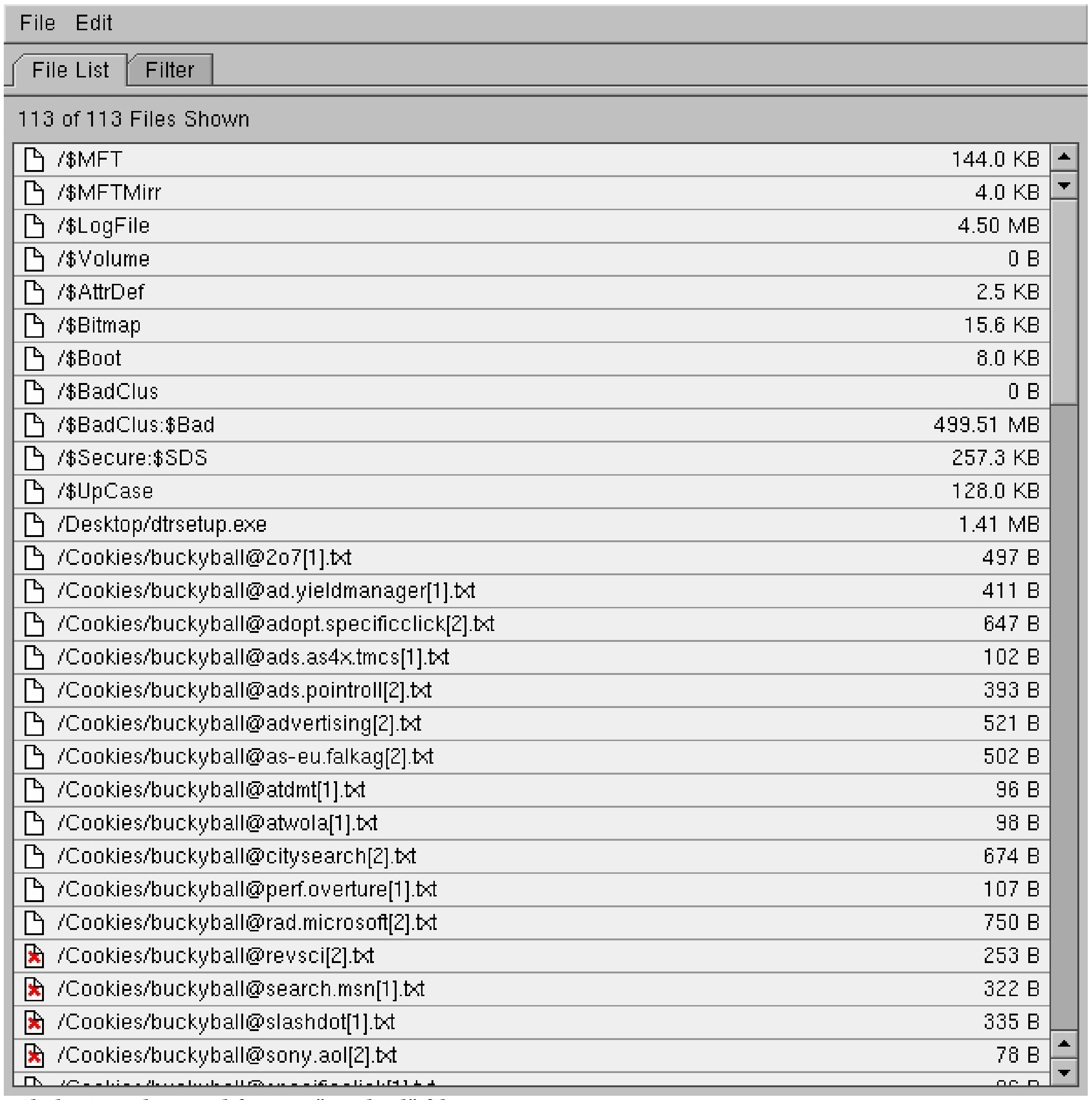


```
499.51 MB (523,776,000 Bytes) of total volume space.
477.17 MB (500,346,880 Bytes) of pure unallocated space.
1 unrecognized/corrupt $MFT record(s) skipped.

Active Objects:
21.62 MB (22,668,140 Bytes) in 102 files.
134.6 KB (137,860 Bytes) in file slack space.
264.3 KB (270,688 Bytes) in 3 normal named streams.
4.3 KB (4,448 Bytes) in named-stream slack space.

Deleted Objects:
328.2 KB (336,117 Bytes) in 7 files.
7.3 KB (7,449 Bytes) in file slack space.
0 B (0 Bytes) in 0 named streams.
0 B (0 Bytes) in named-stream slack space.
0 data bytes are overwritten by active data.

Misc Stats:
Sectors per Cluster: 8
Bytes per Cluster: 4096
Media Descriptor: 248
Sectors in Volume: 1023000
$MFT LCN: 42625
$MFTMirr LCN: 63937
$MFT Offset: 174592000
Bytes per FILE: 1024
Bytes per INDX: 4096
Volume Serial Number: 16487788199052302582
$MFT Records: 144
```

File system information - obtained from an FS "Study".

At the bottom of this output, we see options that allow us to export a full file listing as an HTML file or as a tab-delimited file (suitable for importing into spreadsheets, etc.).

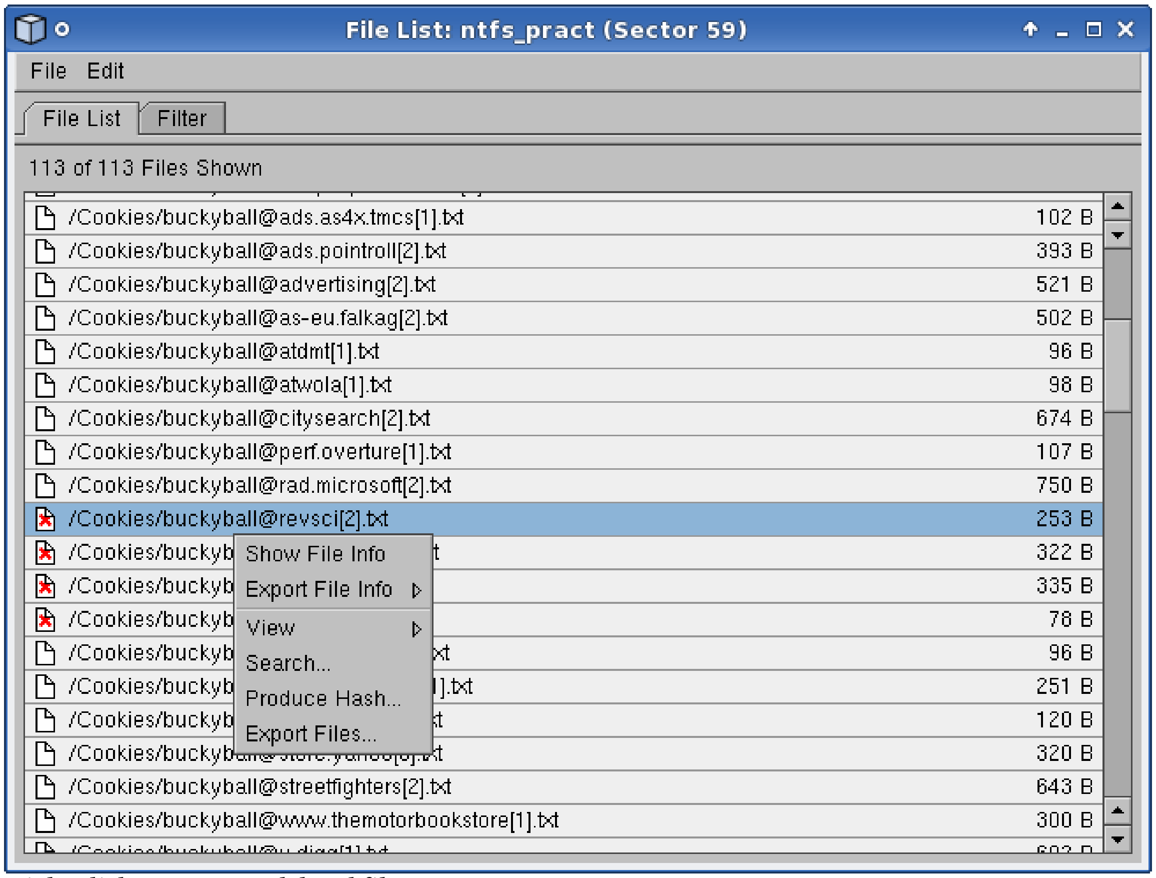
Note also that we can directly view a file list using the “File List” button. In addition to giving us access to a visual representation of the file list (to include deleted files), this is also where we can go to start our logical analysis.



113 of 113 Files Shown

```
/$MFT                                                  144.0 KB
/$MFTMirr                                                4.0 KB
/$LogFile                                              4.50 MB
/$Volume                                                   0 B
/$AttrDef                                                2.5 KB
/$Bitmap                                                15.6 KB
/$Boot                                                   8.0 KB
/$BadClus                                                  0 B
/$BadClus:$Bad                                       499.51 MB
/$Secure:$SDS                                          257.3 KB
/$UpCase                                               128.0 KB
/Desktop/dtrsetup.exe                                  1.41 MB
/Cookies/buckyball@2o7[1].txt                            497 B
/Cookies/buckyball@ad.yieldmanager[1].txt                411 B
/Cookies/buckyball@adopt.specificclick[2].txt            647 B
/Cookies/buckyball@ads.as4x.tmcs[1].txt                  102 B
/Cookies/buckyball@ads.pointroll[2].txt                  393 B
/Cookies/buckyball@advertising[2].txt                    521 B
/Cookies/buckyball@as-eu.falkag[2].txt                   502 B
/Cookies/buckyball@atdmt[1].txt                           96 B
/Cookies/buckyball@atwola[1].txt                          98 B
/Cookies/buckyball@citysearch[2].txt                     674 B
/Cookies/buckyball@perf.overture[1].txt                  107 B
/Cookies/buckyball@rad.microsoft[2].txt                  750 B
/Cookies/buckyball@revsci[2].txt                         253 B
/Cookies/buckyball@search.msn[1].txt                     322 B
/Cookies/buckyball@slashdot[1].txt                       335 B
/Cookies/buckyball@sony.aol[2].txt                        78 B
```

File listing obtained from a "studied" file system



```
113 of 113 Files Shown
/Cookies/buckyball@ads.as4x.tmcs[1].txt              102 B
/Cookies/buckyball@ads.pointroll[2].txt              393 B
/Cookies/buckyball@advertising[2].txt                521 B
/Cookies/buckyball@as-eu.falkag[2].txt               502 B
/Cookies/buckyball@atdmt[1].txt                       96 B
/Cookies/buckyball@atwola[1].txt                      98 B
/Cookies/buckyball@citysearch[2].txt                 674 B
/Cookies/buckyball@perf.overture[1].txt              107 B
/Cookies/buckyball@rad.microsoft[2].txt              750 B
/Cookies/buckyball@revsci[2].txt                     253 B
/Cookies/buckyb                      t               322 B
/Cookies/buckyb                                      335 B
/Cookies/buckyb                                       78 B
/Cookies/buckyb                      xt               96 B
/Cookies/buckyb                      ].txt           251 B
/Cookies/buckyb                      t               120 B
/Cookies/buckyb                      .txt            320 B
/Cookies/buckyball@streetfighters[2].txt             643 B
/Cookies/buckyball@www.themotorbookstore[1].txt      300 B
```

Right click menu on a deleted file.

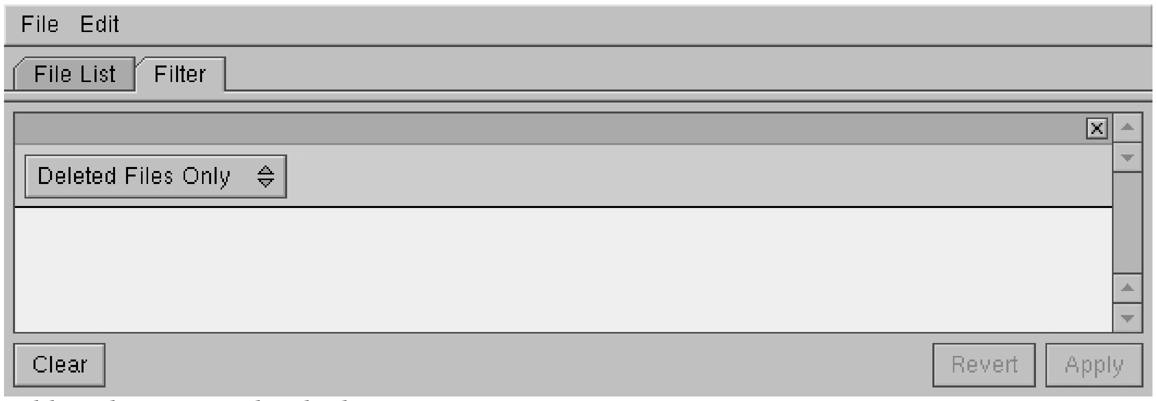
The right click menu displayed for a file in a file listing allows you to perform a number of tasks. In the above screen shot, we see that we have the ability to export the contents or view detailed information of the deleted cookie file.

SMART Filtering

Within SMART, there are two major ways to parse for information. The first is by using "filtering". Filtering works at the logical level. Filters are based on file meta data like modified, accessed and created times; or filenames and extensions; or attributes like "deleted or allocated", etc. The other method is by "searching", which is done at the physical level using either complex expressions or simple terms. We will briefly describe each method here, starting with filtering.

Continuing with our file list, let's move to the "Filter" tab. The filter list is currently empty. Right click in the empty space and select "*Add New Filter --*

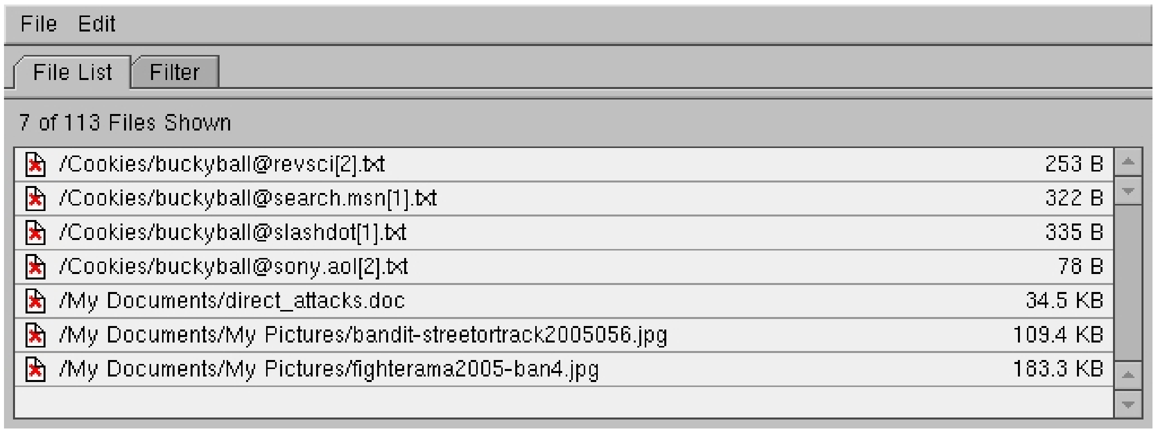
> *Active/Deleted Filter*". This simple filter, when applied using the button at the bottom of the dialog, will alter our file list to show only deleted files:



Deleted Files Only

Adding the Active/Deleted Filter

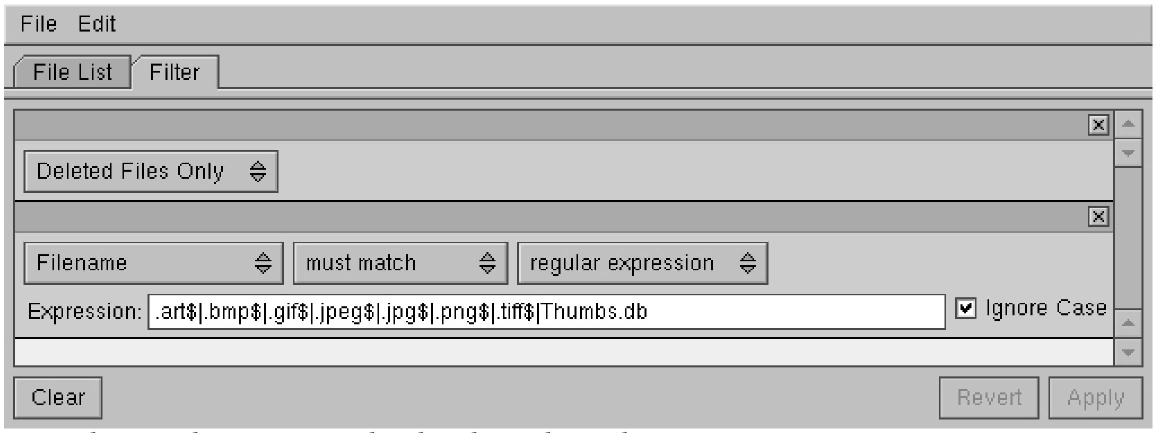
Clicking back on our "File List tab" shows us all seven of the deleted files we identified in our earlier Sleuthkit exercise:



```
7 of 113 Files Shown
/Cookies/buckyball@revsci[2].txt                                   253 B
/Cookies/buckyball@search.msn[1].txt                               322 B
/Cookies/buckyball@slashdot[1].txt                                 335 B
/Cookies/buckyball@sony.aol[2].txt                                  78 B
/My Documents/direct_attacks.doc                                  34.5 KB
/My Documents/My Pictures/bandit-streetortrack2005056.jpg        109.4 KB
/My Documents/My Pictures/fighterama2005-ban4.jpg                183.3 KB
```

SMART also comes with a decent set of predefined filters that can be used "out of the box". These are listed under the right click menu item "Term Library".

The ability to "stack" filters provides even more power. Suppose we want to view only a list of deleted graphical images. We leave the "*Active/Deleted*" filter in place, right click in the empty space below it and select "*Term Library --> Graphics Files*". Note that the predefined filter "*Graphics Files*" is populated with expressions that will identify graphics images by their extensions. This set of expressions can be further adjusted to include or exclude files depending on the examiner's preference.



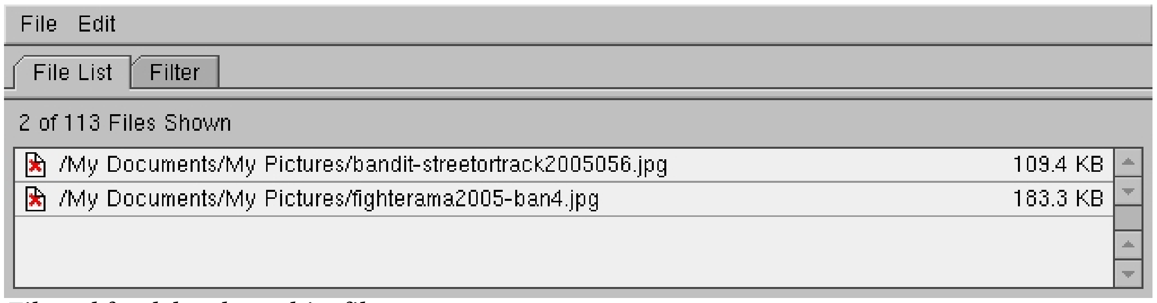
Deleted Files Only

Filename | must match | regular expression

Expression: .art$|.bmp$|.gif$|.jpeg$|.jpg$|.png$|.tiff$|Thumbs.db [✓ Ignore Case]

Two Filters in place: Active/Deleted and Graphics Files

After applying the above stacked filters, our file listing is paired down to only deleted graphics files.



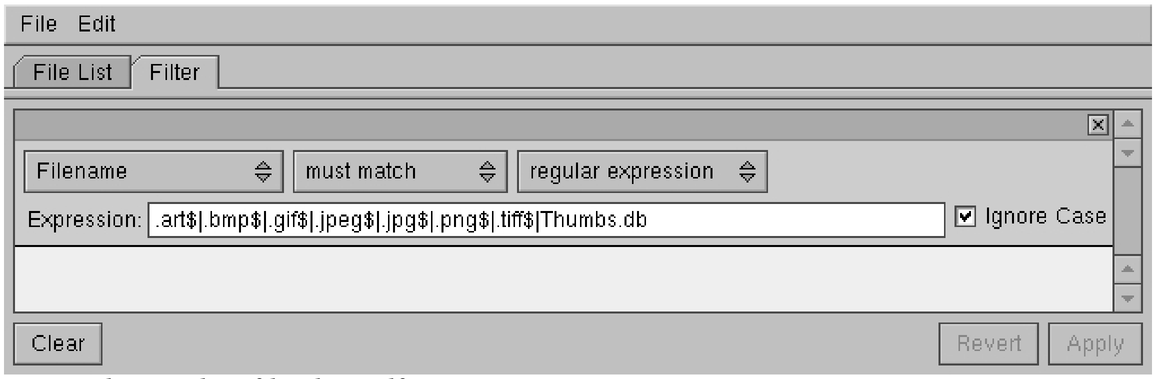
```
2 of 113 Files Shown
/My Documents/My Pictures/bandit-streetortrack2005056.jpg    109.4 KB
/My Documents/My Pictures/fighterama2005-ban4.jpg            183.3 KB
```

Filtered for deleted graphics files

SMART Filtering – Viewing Graphics Files

SMART has a built in graphics viewing capability that allows you to view images in a separate window. Thumbnail images can be browsed or reviewed using a configurable slide show function.   Individual files can be selected for viewing, or groups of files can be displayed together.

To illustrate this capability, let's load the *Graphics Files* filter, by itself, from SMART's filter term library. Note that filters can be cleared from the filter list by clicking on the small box with the “X” in the top right hand corner of the filter definition.



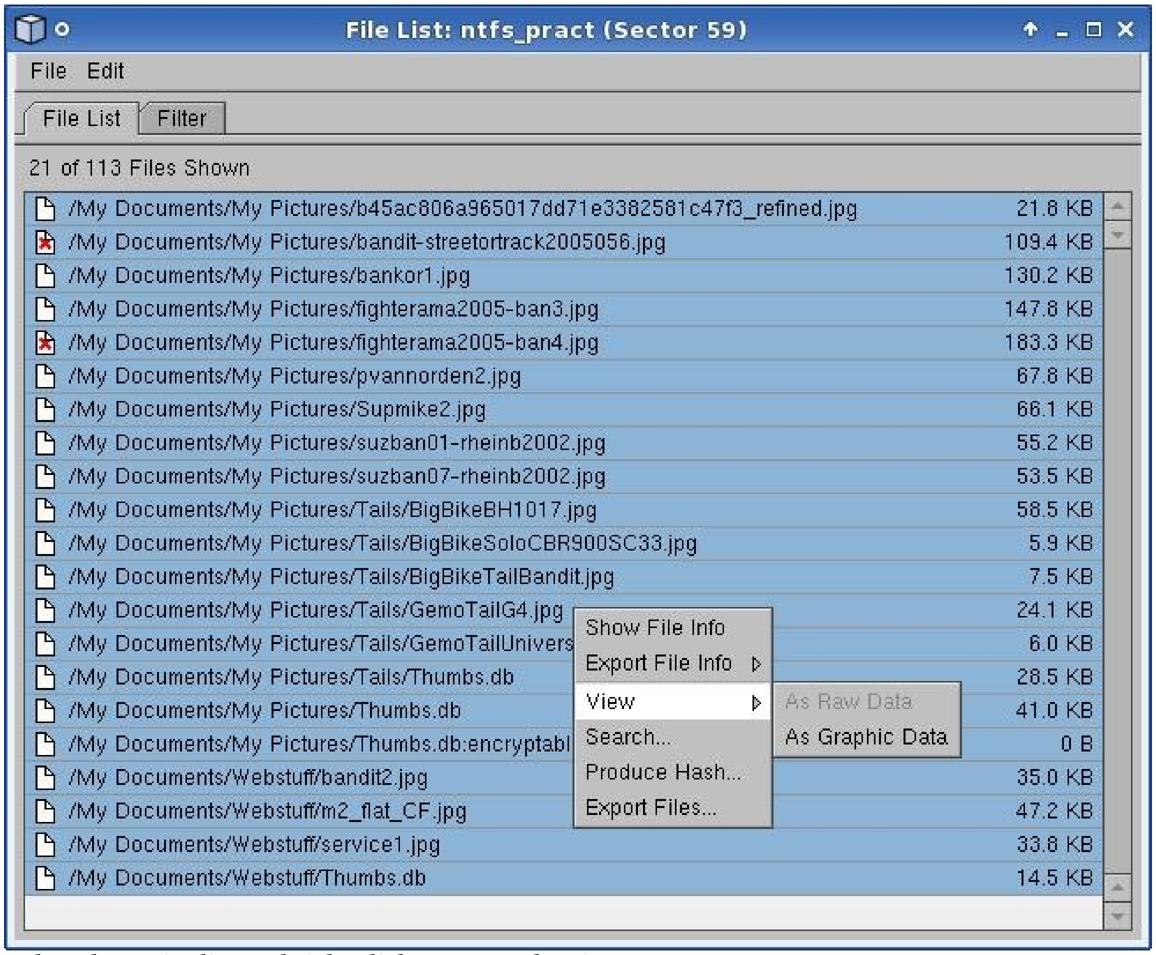
Filename | must match | regular expression

Expression: .art$|.bmp$|.gif$|.jpeg$|.jpg$|.png$|.tiff$|Thumbs.db

☑ Ignore Case

Setting the Graphics filter by itself

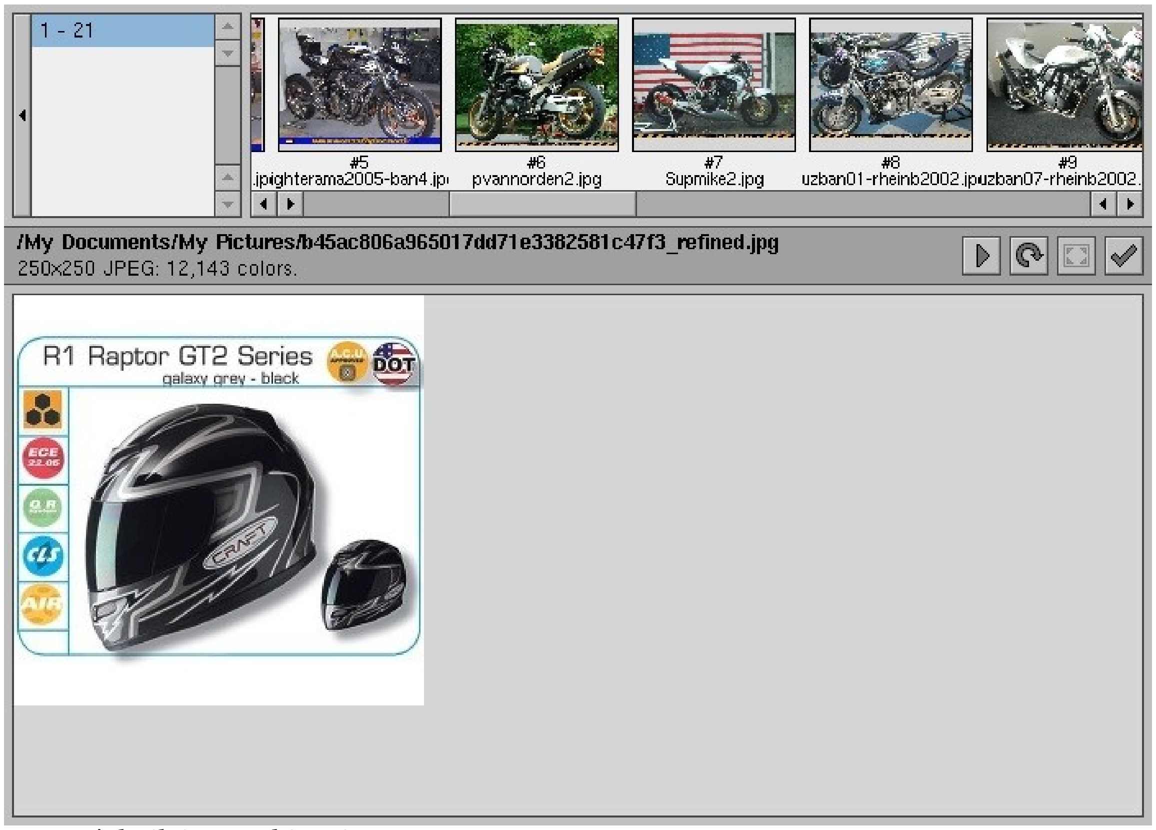
The resulting file list shows us all the graphics files (by extension, from our filter expression) within the selected partition (NTFS partition at sector offset 59, from the main SMART window). Left click on the top file to select it, then shift+left click on the bottom file to select the entire list. Right click on the selected area, and go to "*View --> As Graphic Data*".



```
21 of 113 Files Shown
/My Documents/My Pictures/b45ac806a965017dd71e3382581c47f3_refined.jpg   21.6 KB
/My Documents/My Pictures/bandit-streetortrack2005056.jpg               109.4 KB
/My Documents/My Pictures/bankor1.jpg                                   130.2 KB
/My Documents/My Pictures/fighterama2005-ban3.jpg                       147.8 KB
/My Documents/My Pictures/fighterama2005-ban4.jpg                       183.3 KB
/My Documents/My Pictures/pvannorden2.jpg                                67.8 KB
/My Documents/My Pictures/Supmike2.jpg                                   66.1 KB
/My Documents/My Pictures/suzban01-rheinb2002.jpg                        55.2 KB
/My Documents/My Pictures/suzban07-rheinb2002.jpg                        53.5 KB
/My Documents/My Pictures/Tails/BigBikeBH1017.jpg                        58.5 KB
/My Documents/My Pictures/Tails/BigBikeSoloCBR900SC33.jpg                 5.9 KB
/My Documents/My Pictures/Tails/BigBikeTailBandit.jpg                     7.5 KB
/My Documents/My Pictures/Tails/GemoTailG4.jpg                           24.1 KB
/My Documents/My Pictures/Tails/GemoTailUnivers                           6.0 KB
/My Documents/My Pictures/Tails/Thumbs.db                                28.5 KB
/My Documents/My Pictures/Thumbs.db                                      41.0 KB
/My Documents/My Pictures/Thumbs.db:encryptabl                              0 B
/My Documents/Webstuff/bandit2.jpg                                       35.0 KB
/My Documents/Webstuff/m2_flat_CF.jpg                                    47.2 KB
/My Documents/Webstuff/service1.jpg                                      33.8 KB
/My Documents/Webstuff/Thumbs.db                                         14.5 KB
```

Select the entire list and right click to access the view menu

This will automatically open the graphics catalog. Also note that selected files can be hashed, exported or have detailed information displayed.



SMART's built in Graphics Viewer

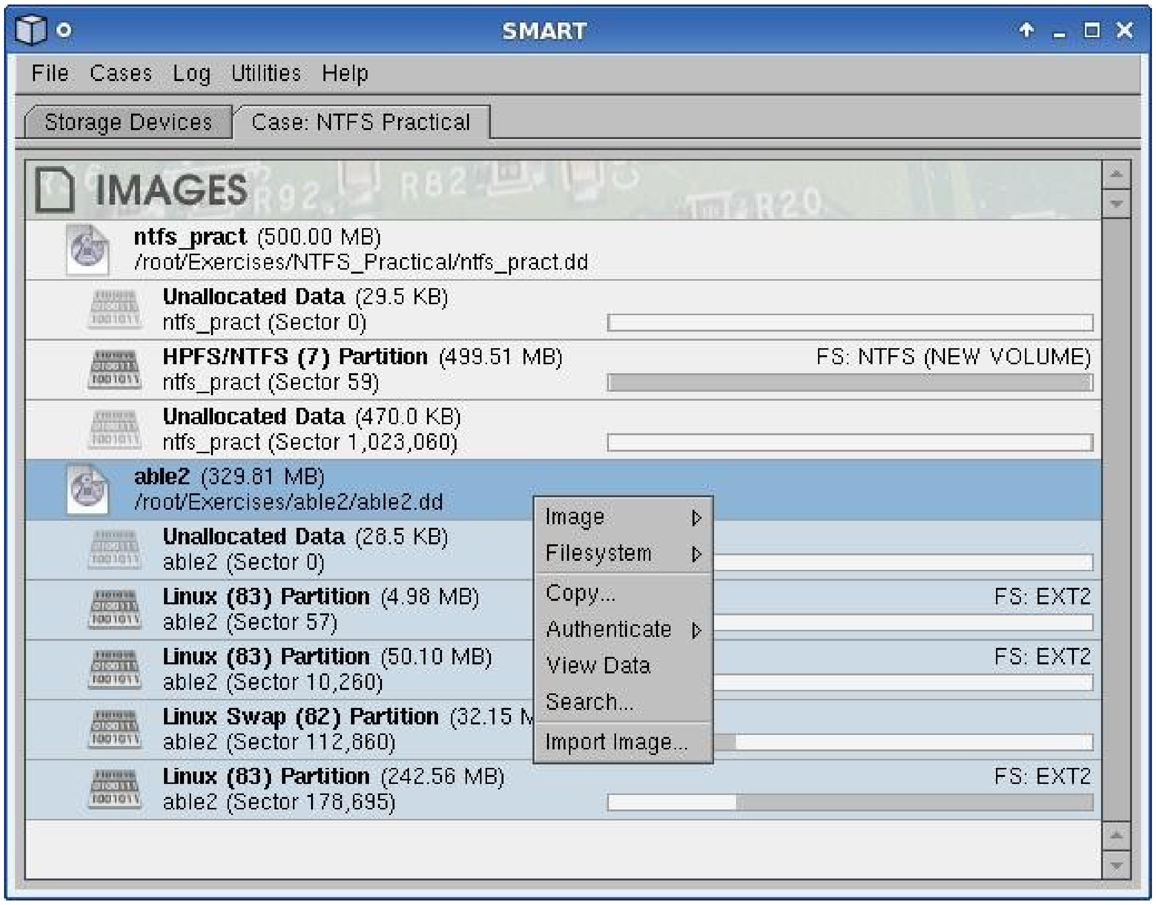
From this window, the files can be browsed by pointing and clicking, or viewed via the slide show mentioned earlier. The slide show speed is set under the "*File --> Preferences*" dialog in the main SMART window. Files of particular interest can be "flagged" and marked with comments.

SMART Searching

In addition to the filtering capability, SMART has a powerful search function. As with most SMART commands, this one is also accessed through the right click menu.

To illustrate SMART's searching ability, we will duplicate our string search within the *able2.dd* image. Recall in Sleuthkit Exercise #2 we searched our disk image for the simple string "*cybernetik*". We will do the same here, and compare the output. First we must add our *able2.dd* image to our current case in SMART's main screen. Alternatively, you can open another case and add the image there.

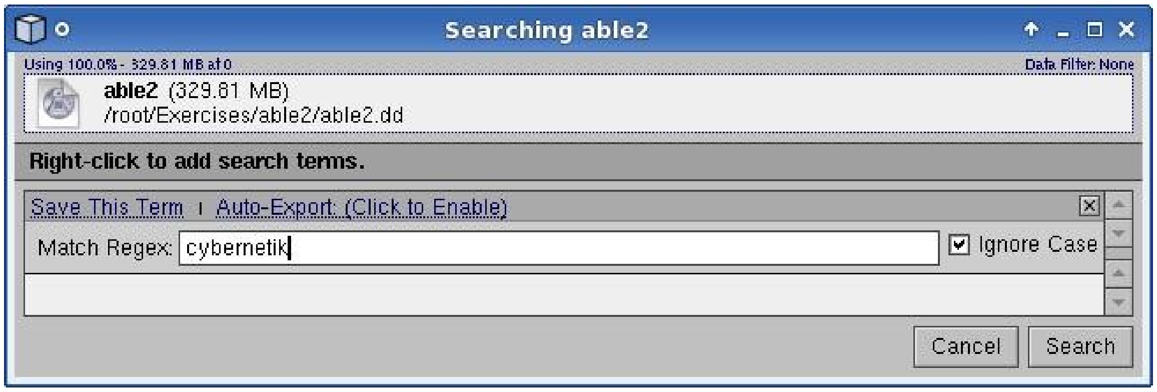
Once the image has been added, from the main Case screen, right click on the *able2.dd* image and select "*Search*". We are clicking on the image entry, not on any particular partition, remember we want to search the entire image.



ntfs_pract (500.00 MB)
/root/Exercises/NTFS_Practical/ntfs_pract.dd
Unallocated Data (29.5 KB)
ntfs_pract (Sector 0)
HPFS/NTFS (7) Partition (499.51 MB) FS: NTFS (NEW VOLUME)
ntfs_pract (Sector 59)
Unallocated Data (470.0 KB)
ntfs_pract (Sector 1,023,060)
able2 (329.81 MB)
/root/Exercises/able2/able2.dd
Unallocated Data (28.5 KB)
able2 (Sector 0)
Linux (83) Partition (4.98 MB) FS: EXT2
able2 (Sector 57)
Linux (83) Partition (50.10 MB) FS: EXT2
able2 (Sector 10,260)
Linux Swap (82) Partition (32.15 M
able2 (Sector 112,860)
Linux (83) Partition (242.56 MB) FS: EXT2
able2 (Sector 178,695)

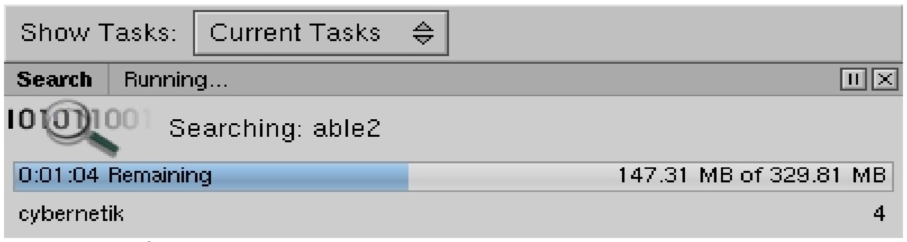
In the resulting search window, right click again on the empty space and select "*Add New Term --> Simple Term*". Note that the search function also comes with an extensive library of search terms available to assist an examiner in finding common artifacts. In the resulting term box, type "*cybernetik*".

Remember that we are searching the entire disk for this string, just as we did in the previous Sleuthkit exercise.



```
Searching able2
Using 100.0% - 329.81 MB at 0                                    Data Filter: None
able2 (329.81 MB)
/root/Exercises/able2/able2.dd
Right-click to add search terms.
Save This Term | Auto-Export: (Click to Enable)
Match Regex: cybernetik                                          [✓] Ignore Case
                                                         Cancel   Search
```

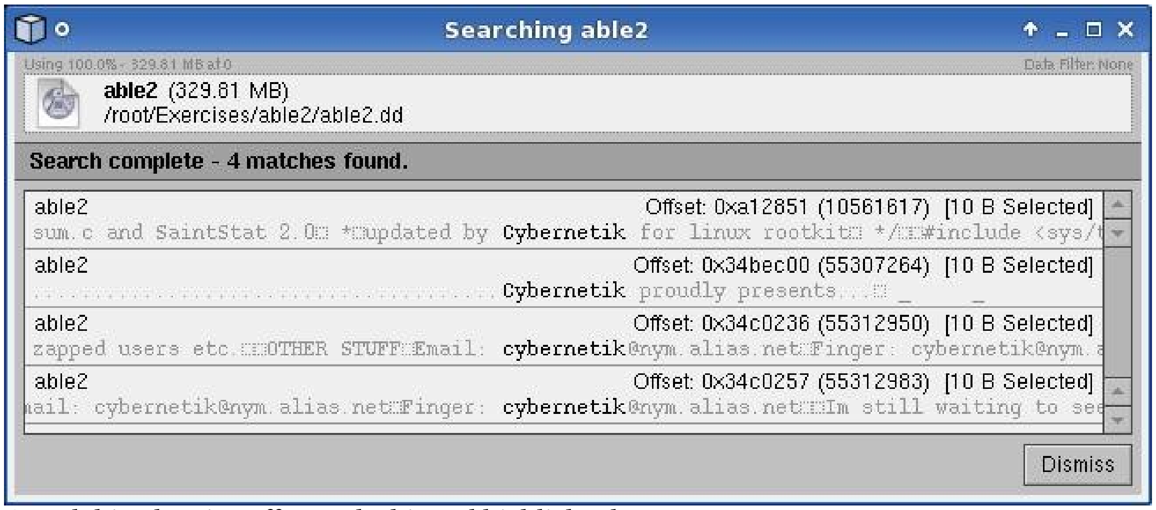
When the search is started, you are presented with a progress indicator.



```
Show Tasks: Current Tasks
Search   Running...
Searching: able2
0:01:04 Remaining                              147.31 MB of 329.81 MB
cybernetik                                                          4
```

Progress indicator

The results are then displayed:

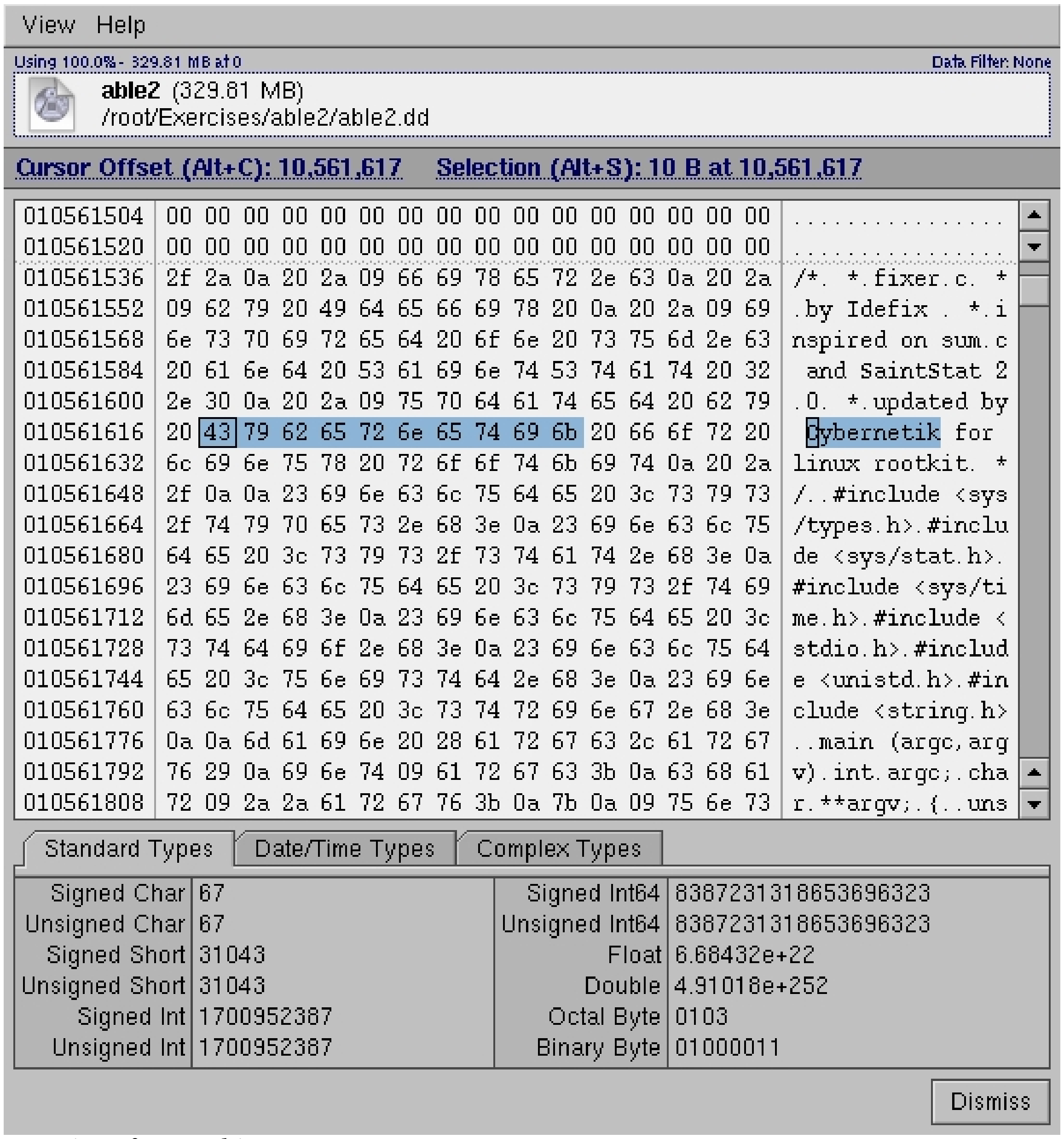


```
Searching able2
Using 100.0% - 329.81 MB at 0                                    Data Filter: None
able2 (329.81 MB)
/root/Exercises/able2/able2.dd
Search complete - 4 matches found.
able2                                   Offset: 0xa12851 (10561617)  [10 B Selected]
sum.c and SaintStat 2.0 *updated by Cybernetik for linux rootkit */#include <sys/t
able2                                   Offset: 0x34bec00 (55307264)  [10 B Selected]
.................................... Cybernetik proudly presents... _   _
able2                                   Offset: 0x34c0236 (55312950)  [10 B Selected]
zapped users etc.OTHER STUFFEmail: cybernetik@nym.alias.netFinger: cybernetik@nym.a
able2                                   Offset: 0x34c0257 (55312983)  [10 B Selected]
ail: cybernetik@nym.alias.netFinger: cybernetik@nym.alias.netIm still waiting to see
                                                                         Dismiss
```

Search hits showing offset to the hit and highlighted context

As with our previous *able2.dd* search exercise, we have four hits. Review the output of our **grep** string search of *able2.dd* on page 147. Upon examination, we see the these are the same four hits. The offsets provided by our original **grep** command and SMART differ slightly as a result of how the offsets are calculated. Recall that **grep** works on *lines* of output, while SMART does not. The hits, however, are the same.

We can right click on the first search hit and view as raw data, providing us a hex view of the search hit in context. Compare this output with output of our **xxd** command on page 148.


View Help
Using 100.0% - 329.81 MB at 0
Data Filter: None
able2 (329.81 MB)
/root/Exercises/able2/able2.dd
Cursor Offset (Alt+C): 10,561,617
Selection (Alt+S): 10 B at 10,561,617
Standard Types
Date/Time Types
Complex Types
Dismiss

```
010561504  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
010561520  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
010561536  2f 2a 0a 20 2a 09 66 69 78 65 72 2e 63 0a 20 2a  /*. *.fixer.c. *
010561552  09 62 79 20 49 64 65 66 69 78 20 0a 20 2a 09 69  .by Idefix . *.i
010561568  6e 73 70 69 72 65 64 20 6f 6e 20 73 75 6d 2e 63  nspired on sum.c
010561584  20 61 6e 64 20 53 61 69 6e 74 53 74 61 74 20 32   and SaintStat 2
010561600  2e 30 0a 20 2a 09 75 70 64 61 74 65 64 20 62 79  .0. *.updated by
010561616  20 43 79 62 65 72 6e 65 74 69 6b 20 66 6f 72 20   Cybernetik for
010561632  6c 69 6e 75 78 20 72 6f 6f 74 6b 69 74 0a 20 2a  linux rootkit. *
010561648  2f 0a 0a 23 69 6e 63 6c 75 64 65 20 3c 73 79 73  /..#include <sys
010561664  2f 74 79 70 65 73 2e 68 3e 0a 23 69 6e 63 6c 75  /types.h>.#inclu
010561680  64 65 20 3c 73 79 73 2f 73 74 61 74 2e 68 3e 0a  de <sys/stat.h>.
010561696  23 69 6e 63 6c 75 64 65 20 3c 73 79 73 2f 74 69  #include <sys/ti
010561712  6d 65 2e 68 3e 0a 23 69 6e 63 6c 75 64 65 20 3c  me.h>.#include <
010561728  73 74 64 69 6f 2e 68 3e 0a 23 69 6e 63 6c 75 64  stdio.h>.#includ
010561744  65 20 3c 75 6e 69 73 74 64 2e 68 3e 0a 23 69 6e  e <unistd.h>.#in
010561760  63 6c 75 64 65 20 3c 73 74 72 69 6e 67 2e 68 3e  clude <string.h>
010561776  0a 0a 6d 61 69 6e 20 28 61 72 67 63 2c 61 72 67  ..main (argc,arg
010561792  76 29 0a 69 6e 74 09 61 72 67 63 3b 0a 63 68 61  v).int.argc;.cha
010561808  72 09 2a 2a 61 72 67 76 3b 0a 7b 0a 09 75 6e 73  r.**argv;.{..uns
```

Signed Char	67	Signed Int64	8387231318653696323
Unsigned Char	67	Unsigned Int64	8387231318653696323
Signed Short	31043	Float	6.68432e+22
Unsigned Short	31043	Double	4.91018e+252
Signed Int	1700952387	Octal Byte	0103
Unsigned Int	1700952387	Binary Byte	01000011

Hex View of our 1st hit

Further information can be obtained if the search is started from a particular partition rather than the physical image. Assuming that we "studied" the file systems prior to our search, right clicking on one of our search term hits, and selecting "*File System --> Get File Info*" provides us with information derived from the file system the data located at that offset, including the inode, file meta data, etc.

This is just a very brief overview of SMART's capabilities. The SMART user guide provides far more detailed information. For example, we can use SMART to loop mount the partitions read-only with a simple click and then browse the file system in either a terminal or in the file manager of your choice. This provides us the ability to use all our favorite Linux tools to search the logical file system and display the information we need for our analysis. As with all advanced forensic tools, SMART provides excellent session and Case logging functions.

XI. Bootable Linux Distributions

For so many people, this is the meat and potatoes of what makes Linux such a flexible operating system. Access to a bootable CD drive and the ability to reboot the machine can now give us the power to run a full-fledged Linux box without the need to install. For those who have not seen this in action, the power you can get from a CDROM, or even a floppy disk is amazing. This is not a complete list, but the following bootable distributions can give you some idea of what's available to you. There are many MANY more bootable distributions out there. Just do a Google search on "Linux bootable CD" for a sample.

Tomsrtbt - boot from a floppy

...Because there are those times when you just might need a floppy rather than a CD. This small distribution is the definition of minimalist, and it fits on one floppy. You get a decent set of drivers for NICs and file systems (including FAT and NTFS). There's a basic set of common Linux tools, including **dd** and **rsh** or **nc** for imaging over net connections and more. The installation (to a floppy) can be done in Windows with an included batch file. The floppy holds a surprising number of programs, and actually formats your 1.44 Mb floppy to 1.722 Mb. Find it at http://www.toms.net/rb/

Knoppix - Full Linux without the install

This is a CDROM distribution for people who want to try a full-featured Linux distribution, but don't feel like installing Linux. It includes a full Linux environment and a huge compliment of software. The CD actually holds 2GB of software, including a full office suite, common network tools and just about anything else you're likely to need all compressed to a CD sized image. Please do not consider this a forensically sound bootdisk option. There are plenty of better choices out there. But for a "gee, look what Linux can do" disk, Knoppix is hard to beat. http://www.knoppix.net

SMART Linux - It's bootable!

Smart comes in 2 different boot disk options now, providing an excellent platform with an independently verified forensic tool for acquiring and analyzing physical media. The two SMART Linux versions are a boot CD based on Ubuntu and a boot CD based on Slackware. The hardware detection is excellent. SMART's bootable CD provides an environment that you can be sure is forensically sound. It comes with a number of forensic tools pre loaded. We've already had a glimpse of SMART's capabilities. http://www.asrdata2.com

Helix – Knoppix based Incident Response

Helix is a bootable CD with a decidedly network forensics feel to it. When booted, it provides a Linux environment based on Knoppix that has been modified for forensic use and provides a huge number of forensics and network applications.

In addition to being a bootable Linux disk, Helix also provides a "Live" Windows response kit. When placed in a running Windows machine, it will provide tools that can be used for gathering volatile system data. A truly diverse tool! The user guide for Helix is excellent, and gives a great overview of some of the tools available on the CD. The Helix developers pride themselves on providing a cutting edge CD with diverse sets of tools, and support for the latest hardware. http://www.e-fense.com/helix/index.php

XII. Conclusion

The examples and practical exercises presented to you here are very simple. There are quicker and more powerful ways of accomplishing what we have done in the scope of this document. The steps taken in these pages allow you to use common Linux tools and utilities that are helpful to the beginner. At the request of many users, this guide has been expanded somewhat to incorporate more advanced tools, and exercises more related to “real world” scenarios.

Once you become comfortable with Linux, you can extend the commands to encompass many more options. Practice will allow you to get more and more comfortable with piping commands together to accomplish tasks you never thought possible with a default OS load (and on the command line to boot!).

I hope that your time spent working with this guide was a useful investment. At the very least, I’m hoping it gave you something to do, rather than stare at Linux for the first time and wonder “what now?”

XIII. Linux Support

Places to go for support:

Aside from the copious web site references throughout this document, there are a number of very basic sites you can visit for more information on everything from running Linux to using specific forensic tools on Linux. Here is a sample of some of the more informative sites you will find:

Slackware. Just one of many Linux distro's.
http://www.slackware.com

Learn Slackware (Slackware Linux Essentials):
http://www.slackbook.org/

Sleuthkit Wiki
http://wiki.sleuthkit.org

The Linux Documentation Project (LDP):
http://www.tldp.org

Open Source Forensic Software:
http://www.opensourceforensics.org

Software:
http://sourceforge.net/

In addition to the above list, there are a huge number of user forums, some of which are specific to Linux and computer forensics. One of my favorite forums (with an open source specific board):

http://www.forensicfocus.com

IRC (Internet Relay Chat)

Try #slackware on the Freenode network (or other suitable channel for your Linux distribution of choice). Many LinuxLEO readers have commented on the enthusiastic help received in #slackware on general Slackware and Linux questions.

A Google search will be your very best friend in most instances.