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PRACTICAL APPLICATIONS OF DIGITAL IMAGING IN THE FIELD OF FORENSIC FIREARMS IDENTIFICATION

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TECHNICAL MEMORANDUM

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The following is a comprehensive review of the field of digital imaging as it pertains to the field of forensic firearms examination. The author provides recommendations for the use and integration of various systems.

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Étude sur l'imagerie numerique en ce qui a trait à l'expertise judiciaire des armes à feu. L'auteur fait des recommandations concernant l'utilisation et l'integration de divers systèmes.

Le Centre canadien de recherches policieres remercie Scott Kashuba pour lui avoir permis de reproduire et de distribuer cet article.

Practical Applications of Digital Imaging in the Field of Forensic Firearms Identification

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Practical Applications of Digital Imaging in the Field of Firearms Identification

Introduction

Digital imaging is quickly replacing the traditional wet-chemistry method of photography presently used in forensic science. Hand held digital cameras, video capture equipment and mass storage options in combination with comparison microscopes, bore scopes and scanning microscopes can provide the forensic firearms examiner with effective methods of documenting, archiving, transferring and presenting their casework. The loss of photographers at some locations and the possible movement towards integrating the remainder into the Documents Section will could require other sections to do their own imaging work.

While digital imaging appears to be the way of the future in forensics, a standard configuration of hardware and software components required for a Firearms Section has not been fully explored. The digital imaging "system" chosen must comprise of universally standard designs, which allows the flexibility to alter, expand, improve, or share the system in order to reduce the chances that it quickly becomes obsolete due to proprietary components.

It is also important to ensure that the digital equipment, chosen by the Firearms sections, integrate into the overall laboratory ROSS network system. Other sections in the laboratory have started the transition to digital imaging as well, and for practical reasons of image management, equipment sharing and image output, each group must be able to interact with each other. This does not mean, however, that each individual section in each laboratory must utilize the same set of equipment and software. Fortunately, industry standards have been developed which allow the use of any compliant product. This will allow each group within the laboratory to utilize their existing equipment, as well as acquire new items to suit their individual needs.
Any imaging system chosen must also balance maximum utilization with quality images and ease of use. There are many options of hardware and software that cover the spectrum of cost and complexity. It would be preferable to have an simple, effective and easy to use system that included all of the image sources within the section than have a state of the art system that was extremely costly, complicated and required extensive training and use to maintain competencies. If a system is hard to operate, or takes a long preparation time for each use, it is not likely to be accepted or utilized by the section members.

This project will explore the field of digital imaging and provide recommendations for systems that can integrate into a laboratory network with a digital imaging section, as well as a "stand alone" system that is suited for more independent operation. These systems can be created in whole, or adapted from systems and equipment already in place in the laboratories across the country. Recommendations will take into consideration many of the required/desired components that may already be present in the various locations. As with all computer hardware and software, any specific recommendations made in this project will likely be obsolete in a few months, however, the concepts and concerns should remain valid.

Digital imaging can be divided into the following main components:

- Image Capture
- Storage
- Image Management
- Transmission
- output

Image Capture

Capturing digital images requires the acquisition and transmission of a digital picture of an object into a computer. These images can be captured by a hand-held digital camera, camcorder, charge coupled device camera, hand-held scanner, flat bed scanner, photograph/negative/slide scanners, 35mm film scanners, bore scope, or other related sources such as a scanning electron or probe microscope. These images can be transferred to the computer via many means, such as a video capture card, or disk drive. Digital images are saved as standardized computer files which allows them to be "read" by various software programs. Once captured, images can be enhanced, stored, transmitted, or printed with these programs by the examiner.

Hand-held cameras

There are many options available when considering a digital hand-held camera. The cameras described here are ones that would be utilized within a firearms section for "everyday" documentation of casework, and are not the more technologically complex units required for the very specialized work done by the photo/imaging section.

In the past year, dozens of models have become available from the major camera and computer companies covering the spectrum of features and price. Each of the cameras will capture an image in a digital file format, store the acquired images, and transmit these images to a personal computer. Each camera is bundled with some type of image enhancement software, the features of which also depends on the model of the camera. The differences between the cameras lies in the technical features, file formats, on-board storage system, and camera/personal computer transfer methods used.

File Formats

There are many industry standard formats for compressing images for computers, of which the Joint Photographic Experts Group (JPEG) is the most common still picture compression format used in the hand-held digital cameras. Normally, VGA size data images take up approximately 1 Mb of memory per 1 line of horizontal resolution. By using a compression ratio of 1/5, fine (higher resolution) images that would take up 1 Mb of space can be reduced to take up 100 kb. This means that instead of one image per 1.44 Mb floppy disk, there can be 20 fine resolution or 40 standard resolution images stored on the same disk.

Other file formats are utilized in image storage and will be described in a later section.

Camera On-board Storage

There are three types of image storage found in the low cost (> $1000)digital hand-held cameras studied here: random access memory (RAM), 1.44 Mb floppy disk, and SmartMedia floppy disk. Cameras with the latter two methods generally have small LCD screens built into them that allows the viewing, arranging, and deletion of images before they are transferred to a computer. This option allows the examiner to take a variety of images, determine which if any meet their needs and retake more if necessary without the usual wait and cost of film development.

Random Access Memory - This type of storage, found on the lowest cost digital cameras, is the most simple yet the most inflexible type of image storage. Because this storage is electronic, images acquired must be downloaded into a computer before the camera power is turned off,

1.44 MB Floppy Disk - Currently only available on the Sony Mavica digital camera series, this method of image storage provides the flexibility of storing images on a standard computer floppy disk which ensures low cost media. These disks can hold approximately 20 fine resolution or 40 standard 640x480 pixel JPEG images.

SmartMedia Floppy Disk - This storage medium has become the industry standard for flash memory removable image storage. It is available in 2 Mb and 4 Mb versions. The 2 Mb disk can hold approximately 25 fine mode 640x480 pixel JPEG images.

Camera to Computer Transfer Methods

Once images have been captured by a digital hand-held camera, they must be transferred to a computer for further work. There are many ways to accomplish this:

1.44 Mb Floppy Disk - The *Sony Mavica* cameras store images on standard 1.44 Mb floppy disks which can be placed directly into the floppy drive of the computer for manipulation, storage, transmission, or output.

SmartMedia/PCMCIA Type II card adapter - The SmartMedia card can be removed from the digital camera, placed into an adapter and inserted into a PCMCIA Type II card reader in either a desktop or laptop computer. Images can then be read from this drive and used by the imaging software. The Toshiba PDR-2 digital camera has a PCMCIA card built into it allowing the user to plug it directly into computer equipped with a Type II card reader.

SmartMedia/Floppy adapter - Toshiba intends to release a SmartMedia/floppy disk adapter that allows the user to place the SmartMedia disk into a standard floppy drive.

Serial RS-232 cable - Many digital cameras also have the option of transferring image files through a cable connected to a computer serial port.

Hand-held Video Cameras

Hand-held video cameras, or camcorders, can also be used to obtain images that can be captured in digital form. This is done by introducing the National Television Standards Committee (NTSC) video signal into the computer through the use of a video capture card or add-on device. This capture hardware can range in price and complexity depending on the needs of the user. The problem with this type of signal is that a 30 second video stream contains approximately 900 separate images to process and store. Fortunately, there are devices to handle the capturing of individual frames. Camcorders are connected directly to these devices by their video out cables or via the output of a video tape recorder. The video capture device will then convert (digitize) the pictures into pixels and display it on the screen. Images of crime scenes, firearms functioning or impact examinations, etc., can be imported into the computer. In reality, any modern camcorder can be used in this capacity. The Canon CCD digital video camcorder/camera Model XL1 accepts interchangeable video and 35mm lenses and does not require a capture device for transferring information to a computer.

Parallel Port Frame Grabbers

These external devices, such as the Snappy, Grabbit!, etc. are designed to connect the video source through the parallel port of a computer. They are relatively simple to install and operate and can be moved from computer to computer if required. They grab frames of video from an input source and the companion software allows storage and manipulation of the created digital image. While suitable for occasional use, these devices are not suitable for regular use in acquiring images for archive purposes.

Charge Coupled Device (CCD) Cameras

A charge coupled device camera provides the technology that allow color scanning to the computer with low cost and high quality. It uses memory chips that are sensitive to light as well as electricity. CCDs are made up of thousands of small detectors that when hit with light give off an electrical signal based on the amount. Analog to digital converters translates the resulting voltage into numbers, with the strength of this voltage determining the brightness of the color.

CCD cameras are the most suited for connection to comparison microscopes and bore scopes. In these cameras, the CCD scanners have their sensors arranged in the shape of a square which allows it to scan an entire image at once. The scanner only has to gather and reflect the light into the small square of the array. Many of the firearms sections have one or more of these cameras already hooked to their comparison microscopes or bore scopes. All that is needed to transfer digital images is to connect the video signal cable to a computer video capture device.

Hand-held optical scanners

Hand-held scanners are the least expensive type of scanners available. The scanner is slowly pulled across the object to be scanned. A light is shined through the window in the bottom of the scanner which reflects off the object and is detected by a CCD. Rollers in the bottom of the scanner determine how fast it is being dragged across the object in order to match the scan rate to the resolution desired. The higher the resolution desired, the slower the rate at which the scanner must be pulled across the object.

Hand-held scanners are useful when a scanner is needed away from the section. They can also be used for scanning objects that can not be laid flat. The portability of the hand-held scanner, however, is also a disadvantage as the width of the scan window is usually about 4 to 5 inches across. This means that computer software is required to "stitch" multiple scans together in order to form a whole image of a large object. The effectiveness of-this process is very dependent of the person using the scanner. If the strips scanned are not uniform across the object in direction and speed, the image can become distorted. The additional time required by the computer software to reassemble the image also limits this method of scanning in effectiveness, Although these devices were once an inexpensive option of creating digital images of objects, the dramatic drop in the price of flatbed scanners has made hand-held scanners nearly obsolete for general purpose duties. Hand held scanners are also being phased out by many manufacturers and existing units may not be supported much longer.

Flat-bed scanners

Once considered to be suited only for high-end graphic computer systems, technological advances and the resulting price drop of mass production have made low cost, relatively high quality flat-bed scanners available to the average computer user. These devices can be used to capture digital images of typewritten documents, diagrams, or pictures. Flat-bed scanners have their CCD sensors arranged in a thin line. This means that in order to scan an object, either the object must move across the CCD sensor or the CCD sensor

must move across the object. All modern CCD flat-bed scanners use mirrors to move down the object instead of the CCD unit, which allows the CCD to capture each row of data along the length of the object.

Flat-bed scanners normally capture reflected light from opaque (non-transparent) images, although transparency scanning devices are usually available as options. Because CCDs measure only the amount of light hitting them, not the color of the light, the incoming light is split into the three primary colors (red, green, and blue) and scanned separately if a color image is required.

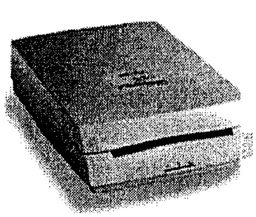
This light splitting can be done in three different methods: three-light, three-filter, or triple-sensor/single pass. The three-light method scans the three times, each pass with one of the three primary colors or a color image or one pass for a gray scale image. A three-filter scan uses a single white light to illuminate the image. This light passes through a colored filter before entering the CCD, with three passes made, each filtered by the different primary colors.

The triple-sensor or single pass scanner produces all the color data in one pass by reflecting the original white light into three different primary beams, Each of these beams is detected by a separate CCD which increases the scanning speed and reduces the likelihood of the object shifting over a series of three scans. The single pass method is quickly becoming the industry standard for scanners in all price ranges.

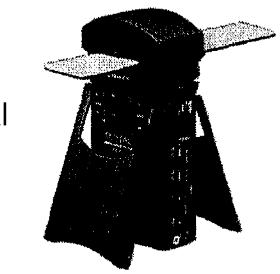
There are also two methods of connecting a flat-bed scanner to a computer: through parallel port or a dedicated expansion card connected to the motherboard. As with all computer hardware options, each connection method has advantages and disadvantages. Attaching the scanner to the computer through the parallel port allows the scanner to be easily moved from computer to computer. The trade-off for this portability is the slower transfer speed between the scanner and the computer. The expansion card option allows the fastest transfer speed of the scanned image, up to 80% faster in some cases, but means that the scanner can only be used with a computer equipped with a compatible card. The most common type of expansion card is a Small Computer Systems Interface (SCSI) which also allows the user to connect an additional six other SCSI devices through the same controller card.

Photograph/Negative/Slide Scanners

Photograph/Negative/Slide scanners are used to capture digital images of existing negatives or slides. They can be very useful in the archiving of pictures of past cases into digital form, or if the particular laboratory has not completely switched to the digital photography format. These scanners can also be used to integrate other agencies photographic work into archives or for lectures when used with software packages from companies such as Microsoft or Corel. These scanners can

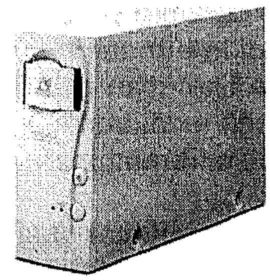


produce high quality and high resolution images with resulting increased color depth. This form of scanner is much smaller in size than a flat-bed scanner and many models are manufactured to be installed internally into a 5 1/4"expansion bay of a personal computer.



. Film Scanners

35mm film scanners are now being produced by the major photographic manufacturers. These devices eliminates the need for the printing of photographs, negatives, or slides then scanning them into the computer. Once the film is processed, the cartridge is placed in the scanner and read directly into the computer. Each frame can be simultaneously viewed on the screen. These images can then be enhanced, stored, or transmitted as standard digital images. Fuji manufactures a system that combines the scanning of these photographic media into a computer as well as option to output the signal to a video source such as a television.



Bore Scopes

Modern bore scopes can be connected to a CCD camera in order to document the images of the inside of a firearm barrel. These images can be useful in determining the cause of certain accidental characteristics found on fired bullets. As with all standard digital images, the pictures can be used for whatever purpose is required by the examiner.

Scanning Microscopes

Falling prices combined with advances in computer processing speeds and networking capabilities have made scanning microscopes a more practical choice in forensic science. All modern scanning microscopes are equipped with digital imaging hardware and software which enables the capture and storage of images, x-rays, or other outputs that are produced during analysis. Polaroid images that are produced by older units can be scanned into a digital form for use by the computer system.

Video Cards

The video card is the connection between the computer and monitor. There are differences between a dedicated high end video capture card and a graphics card with image capture capabilities. Because this paper is examining imaging from the prospective that any system placed in a firearms section would be used for simple, day to day image capture, dedicated video capture cards will not be examined.

Video cards have evolved as the demand for more sophisticated video capabilities has grown. Many medium to high end cards now incorporate input, capture and output of NTSC video signals. These new cards also include onboard processors which frees up the CPU of the computer from handling the graphics portion of software applications. This is necessary as software becomes more multi-media orientated and the requirements for sound and live video would require too much of the CPU resources.

A modern video card is basically a separate computer with a dedicated processor and RAM. The processor (graphic controller) determines the overall speed of the video card. The more sophisticated it is, the faster it can process information. This RAM is the same as that contained on the motherboard and is used to store information processed by the graphics processor. The more RAM the graphics card has, the better the performance will be.

The initial step in determining the type of video card needed for a given application is to decide what the primary purpose of the card is going to be. The number of colors required by the user is also important in the purchase of a video card. A 16 bit card can produce 65,536 colors, which will display near photographic quality images. A 24 bit card will produce 16.7 million colors at a 1,024x768 resolution.

The vertical refresh rate of your monitor and video card determine how many time the screen image is redrawn. A minimum refresh rate of 72 Hz is necessary as some people will see flickering at 60 Hz. A screen that flickers is likely to cause eye strain and discomfort with extended periods of use. The type of monitor used must also be considered, as a low quality video card will produce a low quality picture on the most expensive monitor while the image from a high quality video card will only be as good as the monitor it is paired with.

Before an image is displayed on the monitor, the video card must transfer the information that is stored in its RAM to the on-board digital-to-analog converter (DAC). The DAC converts this digital information to an analog signal which is sent to the monitor. The most common type of video card memory is dynamic RAM (DRAM). As DRAM can only be read from or written to at any given time, it must switch back and forth between the DAC and processor. If the amount of data being transferred is greater than the limitation of the DRAM, the refresh rate is exceeded, and monitor flicker will be evident.

In order to compensate for this problem, an improved version of DRAM has been developed and called video RAM (VRAM). VRAM is still dynamic but it allows simultaneous reading and writing, which doubles the available bandwidth. A further improved version windows RAM (WARM). This memory can be used on newer video cards that use bus frequencies of 50 MHZ with exceeds the PCI maximum of 33 MHZ.

VRAM and WARM are now standard on higher end video cards.

The latest type of RAM being attached to video cards is synchronous graphics RAM (SCRAM). While it is single ported, and therefore cheaper to manufacture than VRAM and WARM, SCRAM runs at bus speeds of 66 to 100 MHZ which greatly reduces the chances that information will exceed the capacity of the system and produce screen flicker.

Accelerated graphics port (AGP) is the new interface designed as dedicated high performance 3D graphics slot on the Pentium II motherboards. Because an AGP card runs at 66 MHZ instead of the 33 MHZ of the PCI bus, transfer rates jump from approximately 133 MB/sec to a high of 528 MB/sec and therefore will allow workstation quality graphics on desktop machines. Another advantage to the AGP video card is that it can access system RAM directly to accommodate images requiring more memory than the on board capacity. As a separate units, ACP video cards also eliminate other system components from stealing resources needed for the production of video images.

Image Storage

The advantage of the ease of capturing digital information is partially nullified by the vast number of images that can be produced over a short period of time. Unlike photography, digital images do not require chemical processing and are viewable almost immediately. The cost per image is also negligible when compared to photographs, therefore it .does not cost twice as much to take twice as many images.

A digital image can vary in size depending on the type and complexity of the object (ie. picture, graph, scanned text file, etc.), the resolution it is captured at, and the type of image file it is saved as (ie. jpg, gif, tiff, etc.). The greater the detail, complexity and/or resolution of the image, the larger the size of the file.

The number and size of digital images that can be produced by a section will create special considerations when deciding on file storage. Fortunately, storage alternatives and capacity have increased in flexibility and capacity along with computing power, while decreasing in price.

Image storage is not the only driving force in need for greater storage space. Modern software operating systems and applications are becoming more complex. The size of these programs expands with the new hardware that is developed and therefore begins to compete for both the memory and physical storage capacity of a computer system.

Storage Types

Random Access Memory

Random Access Memory (RAM) is one of the vital components of the modern personal computer. RAM is used by the computer to hold instructions and data needed to carry out software commands and functions. Information is loaded into the memory from a permanent storage device which allows the CPU to use the information as quickly as possible. This reduces the time lag that occurs when the storage device is accessed by the CPU for more information. The more memory a computer has, the more information can be held for quick retrieval. Memory is also important when trying to open large data or image files.

Megabytes of RAM have replaced the kilobytes of the early generations of machines in order to keep up with advancing computer hardware and software requirements. As with other computer components, the price of RAM has dropped dramatically over the past few years, allowing the addition of additional capacity with no extra "relative" cost.

System RAM

System memory is used by the computer to access the operating system, run the code that operates various software programs, as well as temporarily store files, such as word processing or digital images as they are being used. The more RAM a computer has, the faster it can process information because it does not have to access the hard drive and importantly for digital imaging, the more RAM, the larger the image that can be viewed and manipulated. More system memory also means that the user can run more than one software program at a time. This is helpful in digital imaging as it is common for a user to switch back and forth between image manipulation, image capture, and word processing software.

The most common type of RAM is dynamic RAM (DRAM) which must be refreshed periodically so it does not loose its contents. Static RAM (SRAM) does not need to be refreshed but is more expensive to manufacture. DRAM is the simplest type of memory because it is relatively simple in structure and requires less raw materials to produce.

Pentium based machines running Windows 95 or NT require a minimum of 16 MB of system RAM to run the operating system. 32 MB is judged to be a working minimum for general image capturing work and systems that are to be used for image management and/or manipulation should have 64 MB of RAM and ideally 128 MB.

Removable Media

Removable media has also evolved along with the computer. Slow 8" 180 KB floppy disks have been replaced by fast and compact devices that can hold hundreds of megabytes of information. Traditional hard drives are built with fixed capacity. Once they are full, no new information can be stored unless portions of the old information is erased. These hard drives are also designed to remain encased inside the computer and it is therefore difficult and time consuming to remove an old hard drive, install, and transfer the stored information on the replacement.

Removable media, on the other hand, allow for essentially infinite storage capacity. When the media is full, it is replaced by another. In current times, many projects are undertaken by a group of people, some of who many be in a different building, province or country. Files that need to be transferred or shared between project members can be sent electronically over a network or Internet, physically shipped via courier, or carried to meetings.

Five features define the usefulness of removable media in an imaging environment.

Compatibility - Compatibility is perhaps the most important variable in the usefulness of the type of removable media chosen. If images and data stored on a certain type of.,,. media is required to be transferred to another system that is not connected by a network, intranet, or Internet, the media used by both systems must be compatible. In the past, there were fewer types of removable storage and therefore less chance that another computer system may not be able to accept the media. Today, however, there are many more physical types of media which increases the odds of incompatibility.

Portability - In order to be useful, removable media should also be as portable as possible. Portability in this case equates to the physical size of the drives and the media. External drives can be moved from computer to computer if necessary, therefore the smaller the unit is, the easier it is to move. The smaller the media, the easier it is to carry in a pocket or briefcase during transportation or send through the mail.

Versatility - Versatility can be defined as the ability of the media to be used with various types of computer systems (ie. desktop, laptop, instrument, etc.). Versatility also includes the ability to move drives between computers, the software needed to operate it, and the amount of storage that the particular system allows.

Durability - The removable media must be durable enough to stand up to the physical conditions under which it is to be used. This requirement applies to both the drive as well as the media.

Cost - As with other components of a computer, there must always be a trade off between the cost of storage chosen versus the amount of storage per unit. The cost per MB of storage has dropped dramatically in recent times for all types of removable media types.

Off -line vs. On-line storage

Off-line storage is used when computer files are required to be saved but are not needed for immediate access. These files could consist of old case files or images of certain referenced materials. Most modern off-line media consists of tape cartridges or recordable CDs. Tape media suffers from the aspects that information cannot be randomly accessed, writing and reading speed is slow, the cost per megabyte is fairly high, and the tape material is physically more fragile than other storage options, Because they are magnetic in makeup, tapes are susceptible to the same environmental hazards as magnetic removable and fixed disks. For these reasons a tape system is only really suited to systems that require a backup procedure and archiving on a daily basis.

On-line storage is required for files that are constantly changed or being accessed by the systems users. These files would be of a word processing or database type. On-line storage must be re-writable, offer random access to information, reasonably fast in reading and writing information, expandable, and reliable.

Types of On-Line Removable Storage

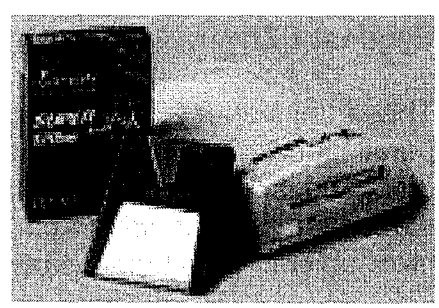
Removable storage is defined as any form of read/write storage that can be removed from a computer. Until recently the only choices were floppy disks and tape drives.

Floppy Disk

The 1.44 MB 3.5" floppy disk has been until recently, the standard removable method fortransferring data to and between computers. It is universal and very inexpensive but has a very low storage capacity for digital imaging purposes. The drive units have been around for almost 10 years with no major mechanical problems and the 3.5" disk is fairly sturdy.

A single, complex digital image can easily exceed the 1.44 MB capacity thus making this type of media unsuitable as the sole type of removable storage in a imaging system. The advantage of this drive/media combination is that it is included with every computer making data transfer uncomplicated.

Imation LS-120



The LS-120, or SuperDisk, appears to be the likely replacement for the 1.44 MB 3.5" floppy drive in the next generation of computers. The LS-120 drive uses disks that are the size of a standard 3.5" floppy disk but can hold 120 MB of data. It can also read standard 3.5" disks and is therefore backward compatible to older systems. The drive can replace the internal 1.44 MB drive, added as an additional floppy drive, or be attached externally to a computer through the parallel port. These drives have already been adopted by many major computer manufacturers for use in their higher-end desktop and laptop systems. The cost of the drive units is close to competing storage systems and will likely decrease as more are manufactured. LS-120 disks are also cost competitive with other similar forms of removable media and no problems have been reported about their durability.

Iomega Zip

The Zip drive broke the storage barrier in removable media by introducing the first "mega" capacity disks. Drives can be installed as internal IDE or SCSI drives or externally using SCSI or parallel interfaces. The units are inexpensive and the external versions are portable enough to be carried with a laptop or transported to attach to another computer system. Iomega software allows computers to be "guest hosts" to the drive which means that once the software is installed, the drive can be moved between, the computers with no further modifications. The drives appear as icons on the Windows 95 desktop and can be accessed by other computers over a network.

The Zip disks are very durable and small in size which allows them to be transported easily. Thev are relatively inexpensive and are produced by all the major media -manufacturers ensuring that they are available from many retail sources.

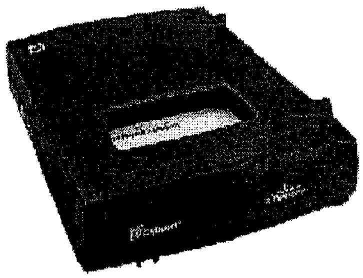
The biggest advantage to the Zip system for mid-size removable storage is there a very high installation base across scientific and academic users which helps ensure compatibility. Many manufacturers now include internal Zip drives as standard or optional equipment, and the use of these drives will onlyincrease.

HiFD 200 MB

Sony has announced a new 200 MB High-Capacity Floppy Disk (HiFD) which may push the lower capacity internal storage systems obsolete in a few years.

Syquest EZflyer 230

These units offer 230 MB storage options. Configurations include external SCSI and parallel units, as well as an internal EIDE version. This drive replaces the earlier EZ135 drive and is backwardly compatible to the 135 MB disks. These drives feature doors that cover the disk opening helping to keep out dust and other contaminant out of the mechanism. The main disadvantage of this system would the lack of an installed



hardware base if the media is to be physically moved from one location to another. If the EZFLYER is used as a local storage option or in conjunction with another, more versatile system, this disadvantage could be minimized.

Fujitsu DynaMO 230

The DynaMO 230 is an internal EIDE drive utilizing 230 MB magneto-optical disks, This unit can also read and write to earlier 128 MB magneto-optical disks. The media offers some advantages over magnetic media, such as Zip or Syquest disks, which can be erased or damaged by electrical fields, or can suffer from head crashes. Optical disks store digital information in the form of magnetic flux directions by altering the magnetic polarity of the bits in the magnetic coating of the disk. This is done by an optical laser instead of a magnetic read/write head. This laser is required to heat the magnetic bits to a very high temperature in order to alter their polarity. When the bit cools, it becomes immune to accidental erasure. The magnet in a traditional magnetic device is always on when writing to the disk. This can introduce the possibility that information that is not meant to be altered or erased can be affected. The rewriting of an optical disk requires two passes of the laser. This means that the laser can only heat and re-polarize those bits that are to be changed. A major disadvantage to this device is the relatively low number of other users, and therefore it should likely be considered to be a secondary or local storage source.

Avatar Shark 250

The Shark 250 provides a 250 MB capacity removable disk in either an internal IDE drive or an external portable drive that connects through the parallel port. The storage media is only usable with this drive and therefore this unit would be a local solution only.

Syquest Sparq

The recently introduced high speed, removable cartridge drive uses 1 GB cartridges. It is currently available in external parallel and internal IDE drives with units priced at under $300 CAN and 1 GB cartridges at $50 CAN. This would be a viable storage solution where outside compatibility is not a vital concern.

Iomega Jaz

The Jaz drive offers 1 GB of removable storage. As with the Zip system, the Jaz drive has become the standard large capacity, removable storage system for the graphics and imaging industries. Units can be purchases in external or internal SCSI configurations. The SCSI interface, while requiring a different or additional expansion card with most Windows based computers, provides a much faster transfer rate than IDE, EIDE or parallel methods. Larger capacity drives, such as the Jaz, are useful when dealing with very large images or a large number of images. The capacity of the Jaz drive is also ideal for arranging images to be "burnt" onto a CD-ROM.

A new generation 2 GB version has been recently introduced which is backwards compatible with the 1 GB cartridges.

The cartridges are essentially small hard drives and as such are not as physically durable as Zip or EZflyer disks. This means that they must be handled and transported with more caution,

Syquest SyJet

At 1.5 GB, this unit currently offers a medium capacity removable cartridge. It is available in internal IDE and SCSI and external parallel and SCSI versions. As with the Jaz drives, the storage capacity and access speed of the SyJet allows it to double as a second hard drive or a substitute for a tape drive for backup purposes as well.

Castlewood Orb 2.16 GB

This new magnetoresistive (MR) drive has a fast 12.2 MB/sec data transfer rate. Units are priced at below $200 US and cartridges at below $30 US. As with many of the other systems, multisite compatibility will be a problem if the cartridges are to be physically moved from one geographical location to another.

Types of Off-Line Removable Storage

Compact Disc - Read Only Memory (CD-ROM)

CD-ROM drives have become standard equipment on all Pentium based computers. Modern drives have access speeds of up to 24 times the original drive capabilities, which allows them to be used for applications that include audio/video clips. Due to their large 640 MB storage capacity, extremely long storage life, low risk of erasure, high installation base, and low cost, the CD-ROM has become the chosen method of software distribution. A CD can hold over 70,000 pages of text as well as audio and video clips.

CDs have pits molded into their surface at the time of manufacture. A layer of aluminum is sandwiched between a layer of clear polycarbonate plastic and a lacquer coating. The polycarbonate has tiny indentations stamped into it during molding. The aluminum layer is used to reflect the laser light while the lacquer is protection against scratching and dust as well as oxidation of the aluminum.

To read the disc, the laser beam is focused through the polycarbonate base onto the aluminum surface. The reflected light varies as it hits the pits and lands of the polycarbonate with the variations recorded as digital “zeros” and “ones”. Both pits and lands represent “zeros” while the transition between pits represents “ones”. Pits and lands can hold no less than three bits and no more than eleven bits of information.

Compact Disc - Recordable (CD-R)

Recordable CD drives and media have become more available and more affordable in the past year. Unlike the conventional CD-ROM units, CD-R drives can write digital information onto recordable compact discs, which can then be read on any computer with a CD-ROM drive.

CD-R discs are different than commercially produced CDs. A CD-R has a polycarbonate base that is similar to a CD but this layer is covered with organic dye rather than aluminum. The dye is the recordable surface of the disc and is covered with an very thin, reflective but inert layer of gold. The CD-R drive directs a laser beam onto the organic dye layer which burns small mounds into the dye surface. These mounds alter the reflectivity of the gold layer simulating the pits of a commercial CD allowing the CD-ROM drive to read the information.

CD-R drives are available in three recording speeds. Single speed (lx) drives will record information at the same speed as the CDs playback. Double speed (2x) records at twice the playback speed which reduces recording time. Quad speed (4x) recorders can record at four times the playback speed. These drives require special 4x media and high speed source drive in order for the recording to be successful. While in theory, time can be saved recording at 2x or 4x, practical experience has shown that lx is remains the best speed to record information in order to be assured of a successful session. Recording sessions can be scheduled to run at lunch time or overnight in order to make effective use of the computer systems time.

CD-R drives are quickly becoming standard equipment on imaging work stations for documenting and archiving information gathered from various sources. Used in tandem with large capacity removable or fixed storage, a CD-R drive can be used to consolidate or archive information dealing with a specific topic, project or person. These drives are referred to as WORM (Write Once Read Many) drives. This means that data can only be “burnt” into the media once. Current CD-R devices allow Multi-Session recording which means that additional data can be written on the media after the first recording session as long as there is enough unused space on the disc. While this feature allows a person to archive as much data as possible on the fewest number of discs, there have been problems with some computer CD-ROM drives accessing multi-session recorded CD-Rs, and therefore a compatibility problem can be an issue. The very low cost of a blank CD-R, the small physical space each disc takes up and the desire to divide information into specific categories should be good arguments to stay to a simple one disc - one information packet policy.

CD-Rewritable (CD-RW)

The rewritable CD format is an emerging technology that, in the past few months, has moved from being a prototype system being reviewed in computer magazines to a product that is available in stores. Developed by Philips Electronics, this drive/media combination allows a user to reuse the specialized CD-ROMs by recording over the information already on the disc. As with all new hardware technology, the initial cost of both the hardware and the specialized CD-Rewritable discs is very high, and at this point, with the lower price of both the drives and media of the CD-Recordable system, it is not feasible for most users to move to this latest method of data storage. The life span and data integrity of these CD-RW discs has also yet to be determined at this point.

Digital Video/Versatile Disc (DVD)

This new version of the CD has a storage capacity of between 4.7 GB and 14.7 GB depending on the version used. This capacity allow for more video, audio, and animation to be stored onto one disk. One problem that could be encountered is that first generation non-rewritable DVD drives may not be able to read CD-R or DVD-RW disks. Another concern at this point is that there is no agreed upon industry standard for the format of these units which can lead to compatibility problems between computers using drives manufactured by different companies.

Danmere Backer 32 PC tape backup

This system allows as much as 4 GB of data storage on a regular video tape by using either an external tape drive kit or internal card which connects to a regular VCR. This would allow the use of existing video equipment and inexpensive video tapes.

Fixed Storage

The hard drive has always been the standard fixed storage medium for personal computers. Originally introduced in a 5 and 10 Megabyte capacity, the amount of the information that can be stored has increased almost exponentially with advances in hard drive technology. Modern hard drives have capacities in the multiple gigabyte range and new developments are making double digit gigabyte capacities possible in the near future.

A major consideration in choosing a hard drive is if the user's requirement is speed of data acquisition or overall storage capacity. Image processing requires a hard drive to have both speed and size. The same file size requirements that are a concern with floppy disks are applicable to hard drives. The difference is that the hard drive could be the primary storage source for multiple users as well as being used for the management and manipulation of images. Although still image processing does not utilize continuous transfers of information between the hard drive and RAM, the files are large due to their high resolution, Saving scanned images and backing up files that are being worked on will also impact the overall amount of time spent by the user.

Hard drives are made up a series of platters which are covered in a magnetic material. These platters are held on a spindle which spins at a very high rate of speed (5400-7200 rpm). The number of platters is determined by the capacity of the unit, with more platters equaling more capacity. Each platter has a read/write head that "floats" just above the surface of the platter. Electric impulses are passed through the head to change the polarity of the magnetic surface. The time the head takes to reach the position of the data it is searching for is called the seek time. Once the head reaches the correct position, it must wait for the platter to rotate underneath it. This time is reduced by a faster spinning drive.

Another consideration is the amount of data per cylinder a drive has. This is defined as the amount of data a drive can access without moving the read/write heads. The more data a head can read the less it will have to move, and therefore the faster it retrieves or writes the information. This means that a drive with a high rate of spin and a high data per cylinder density will be faster than one with the same capacity but lower density.

Built in disk cache size will also influence the speed of a hard drive. The disk cache allows the computer to retrieve the block of data immediately following each one of the blocks the computer requests (read ahead). This feature counts on the fact on the high odds that the next information needed by the computer will be next in line on the surface of the hard drive. A disk cache will also hold the contents of data that is frequently accessed, which reduces the hard drive access time.

The method that the hard drive is connected to the computer's motherboard is very important in the determination of the speed at which it can transfer information back and forth. The standard IDE connection has the slowest transfer rate between the motherboard and the hard drive. The improved EIDE version of this system provides better rates and provides a good balance between speed and cost.

SCSI

SCSI hard drives require an SCSI expansion card to connect them to the motherboard. These hard drives provide faster transfer speeds than traditional units but at a higher price as they have some extra computer hardware built into them. As with all computer hardware, it is necessary to ensure that the other components of the computer can support the high speed of these drives. Most modern SCSI drives use the SCSI-2 interface that can transfer data at 10 MB per second. Wide SCSI units have 61 pin connectors instead of the usual 50 pin and have transfers speeds of 20 MB per second. Ultra-wide SCSI provides an even faster transfer rate at approximately 40 MB per second.

These hard drives must be connected to the computer with an appropriate SCSI accelerator/expansion card. While the SCSI hard drives and expansion cards cost more than standard versions, this interface allows the connection of six additional SCSI devices (such as scanners, removable storage drives, etc.). A second SCSI card can be put into a computer allowing for additional devices. The overall computer system must be considered when deciding on a SCSI hard drive unit. There will be little or no performance gains to moving to one of these drives if the motherboard bus will not pass the information between the RAM, CPU and hard drive as quickly as the components.

Multiple Hard Drives

It is possible to add two or more hard drives to a computer system. These hard drives can be of either IDE and/or SCSI type. This allows for additional non-removable expansion or the separation of software and storage for various functions. A second hard drive can be dedicated solely to the recording of CD-Recordable media. This allows the material needed to be recorded to be arranged exactly as desired and optimized for the recording session. This contents of this drive would be erased after each recording session.

Image Management

File management is perhaps the least standardized component of the digital imaging field. It can be as simple as storing images on specific floppy disks with a hard copy index or as highly complicated as having a server based, multi-site, multi-user database. As with the other components of digital imaging, the choice of a management system depends on the needs and resources of the user(s).

If the images are captured from one or two sources, transferred to and stored on the same computer and output to a dedicated printer, image management can be as simple as a well documented, fixed/removable disk system. Once, however, images need to be shared with others in different local or distant locations, this system will not be sufficient.

If others in other offices at the same location deal with digital images, it is likely that there is at least a LAN present, if not a WAN connecting them to other locations. This means that for maximum effectiveness, one server-based software database overseen by the system administrator could be used. This method would keep a standard interface and management system between users allowing for more effective use of the hardware and software.

Server management will depend on the hardware available, the type and number of users, and the purposes for which digital images were being acquired. Industry standard database or proprietary image software will run on Windows 95 or NT based servers. Server based systems assume that there is some way of transferring acquired images from a capture source to the network. The simplest way of achieving this would be to ensure that the computer that is used to capture or process images is connected directly to the server through a LAN/WAN system. This would allow direct access to files by the users.

Some image management software has the capacity to allow only the alteration of copies of the original captured image. This is important when images are being used to document and/or present forensic images in court where it is vital to be able to prove that no modifications have been made to the evidence. Subsequent copies can be electronically optimized to bring out detail, adjust contrast, enlarge areas, etc..

Transmission

The ability to move files between users is a very important feature of a digital imaging system. The first consideration in the transmission of a digital image from one person to another is compatibility. This compatibility must first be achieved in file format. If the person who receives a file cannot open or use it because it is in a proprietary format, the file is useless. Fortunately, the majority of current digital software and hardware can handle the industry standard formats found in use today.

The second consideration of transfer compatibility to be considered is that if the file is shared via some type of removable media, the recipient of the file must be able to access the media on their computer system. This becomes crucial when the digital file(s) size becomes too large for a standard 1.44 MB floppy disk, and another removable media type is used. Again, if the recipient does not have access to a compatible drive, then the data is useless to them.

The method eliminating the removable media factor in transferring image files between users is to move them electronically via network, Internet or intranet. The method assumes that both the sender and the recipient are connected to a network and/or the Internet. The biggest disadvantage to this method of file transfer is once again that of the image file size. Large files will take a relatively “long” time to send electronically between remote points, although still a much shorter time than sending or transporting removable media. Files transferred between users on the same LAN, however, will not have this time constraint as the files can be read or copied directly from the server.

Output

Printers

Modern ink jet and laser printers can generate high quality prints of digital images. Printers can be connected directly to the dedicated microscope computer or accessed through the network.

Printer Resolution

A printer can be viewed as a pixel converter. Printers convert pixels from the computer memory into dots on some type of physical media. Pixels have no physical dimension, rather they are bits of digital data which are converted into reality by the user as dots on paper. The printer creates a copy of the digital image by converting the pixels to dots. The type of conversion used by the printer will determine the quality of the digital image produced. The types of printer technology used for imaging applications vary in complexity and technology.

Color technology

Computer printers create images by building up patterns of tiny dots of dye. Black and white printers use a variable darkness (shade) of black to provide the detail of an image. Color printers use the subtractive primary colors - cyan, magenta and yellow (CMY). By overlaying two subtractive primaries, the printer can produce red, green and blue. Overlaying all three primaries produces black and the paper supplies the white by default. Most printers include a separate black to ensure dense black for backgrounds and text. This also increases the color cartridge(s) life span. These printers are known as CMYK printers (the K signifying black). These dyes act as filters that absorb certain wavelengths of light and reflect others. The wavelengths that are reflected are seen by the human eye and translated into colors by the brain.

Color printers produce eight basic non-primary colors by creating halftone patterns of dots. For less saturated hues, the printer adds white by leaving some areas unprinted. Complicated half toning can allow a printer to move from eight to the approximately 17 million shades a computer monitor can produce. These halftone patterns determine how many colors the machine can produce as well as the quality of the gradation or transition between colors. Half toning simulates the conventional offset method of printing by grouping smaller dots of different “color” into a bigger dot. Different manufacturers use different numbers of small dots, or cells, depending on the underlying software used to instruct their hardware.

Dye sublimation is an alternative to half toning. This method produces a continuous tone image (photorealistic) by using heat to vary the intensity of the printed dots of color, similar to the concept of conventional photography using variable intensities of light for light and dark regions.

Color Reproduction

Several factors will determine if color produced on the printed page will closely reproduce the color of the original object, captured, or produced on a computer monitor.

Colors that originate from an emitted light source, such as a monitor, scanner or camera, are based on the additive primary colors of red, green, and blue (RGB). Each pixel on the screen has a phosphor of each of these colors. To display a blue object, the monitor uses an electron gun to activate the blue phosphor in the appropriate area. Turning on all the phosphors produces white. Subtle color differences in a single pixel are possible due to the fine control of the electronic system.

For image production and exhibit documentation, consistent color reproduction is critical, whether the source of color is the RGB system of the monitor, scanner, or camera or the CMYK system of the computer system. This consistency is realized by color matching software systems such as the PANATONE matching system, which has become the standard in the graphic arts industry. Colors are standardized by defining them in an objective, device independent format rather than either a RGB or CMYK term. Most major color matching software systems are supported through software packagessuch as Adobe Photoshop.

Printing Technologies

Solid Ink

Phase-change solid ink technology uses solid ink sticks to provide vivid color output on variety of papers. The ink is changed with heat from a solid "phase" stick to a liquid "phase" spray and back to a solid "phase" on the paper upon cooling.

Thermal Transfer

Thermal transfer produces quick and high quality prints and transparencies. Instead of inks, thermal transfer printing uses a transfer roll of colored wax that is divided into consecutive, page sized bands of pigments in wax. Hundreds of individually controlled elements in the thermal printhead are heated to melt spots of color onto compatible paper or film. The paper must make four passes under the printhead, one for each of the CMYK colors.

Dye Sublimation

Dye sublimation, as mentioned earlier, produces continuous tone, photographic-like prints at a fraction of the cost of wet chemistry development. It is especially suited for scanned or bitmap images. Sublimation technology converts a solid to a gas without going through an intervening liquid phase. The coloring agents are in the transfer roll of plastic film that contains consecutive panes of the CMYK colors. As the roll passes across a printhead with thousands of heating elements, the dyes are hot enough to vaporize and diffuse into the papers material. This paper is specially designed to absorb the vaporous dye on contact. The paper is clamped to a drum and makes a separate pass across the transfer roll for each color.

The print head elements have variable heating capabilities and because more dye is transferred with higher temperature, by varying the amount of dye that is transferred, a continuous gradient of color can be produced. Resolutions of 300 to 400 dpi are possible, although the perceived quality of these images is greater to the human eye, compared to inkjet or laserjet versions, because of the continuous tone component of the individual pixels,

Color Laser

Black and white laser printers are now commonplace hardware components of computer systems. Color laser printers, due to their cost, are much less common. Producing a full color image requires separate printing mechanisms for each of the four CYMK colors. This includes a photo receptive drum, a laser beam that exposes areas **not** to be printed, and a dry toner that is applied to areas to be printed. Electrostatic image transfers are made from the drum to the paper and the fusion process can involve heat and/or pressure.

While many color laser printers provide 1200x1200 dpi resolution, there are more supplies and costs associated with their upkeep and operation.

Liquid Ink Jet

A liquid ink jet printer propels fine droplets of liquid ink onto the surface of paper. There are currently a wide range of ink jet printers that vary in price and features, with speed of output and dpi being important factors. Because the ink soaks into the paper, specially designed paper will product better color reproduction that ordinary printer paper. These printers use a dual cartridge system, one for colors and one for black text, with only the least expensive requiring the switching of the cartridges for different printing jobs.

Plain vs Specialized Paper

To produce bright colors that dry quickly and don't run, some of the color medium (ink, wax, toner, etc.) must soak into the paper to form a bond. If too much is absorbed, the color will not be bright, and if too little is absorbed, the medium will run and mix the colors causing detail loss.

Specially treated paper helps with this dilemma by using either short fibers to reduce absorption or a coating to optimize the ink drying time. Disadvantages of this type of paper are the high cost and single use application.

Factors to Consider

Cost

As with computer systems in general, the real cost of a printer must include more than just the purchase price. Features such as memory, network capability, and speed will influence the value of a specific printer. The cost per page of output will also be a very important influence in the real cost of the machine.

Speed

When comparing printer speed (pages per minute), the total time required to from print command to finished output must be considered. Almost every major component of the computersystem will have an effect on this figure as the time needed for the CPU to send the (message to the printer is as important as the time the printer needs to process this command. Printing many copies of the same page requires less time than single copies of many pages.

Printer processing time depends of the power of the processor/controller, the total memory of the printer, and the method of connection between the computer and the printer. A more powerful processor and larger amounts of memory mean that printing jobs can be completely downloaded to the printer by the computer for processing, allowing for the CPU to go on to other tasks.

The communication path (serial, parallel or network) between the computer and printer will also determine the overall speed of a printing job. Networked printers will also be affected by the type of routing a print job has to take (IE. direct or through the server) as well as the overall network traffic delay. Printers have the option to increase printing speed by reducing the print quality.

Compatibility

All modern imaging software applications incorporate Adobe PostScript Level 2 drivers, therefore any printer must be able to support these features,

Connectivity

In order to allow a printer to be accessed by more than one computer, the printer requires a connection either through the computer it is attached to, or to be directly attached to a network system. The direct connection option requires the printer to have a network interface built into it or the expansion slot for a network card.

Ease of Operation

The total utility of a printer will be determined, in part, by its ease of use. A printer that is hard to access, configure, expand, and/or maintain will not be used as much as it should. It should have the capability of printing on different paper sizes and envelopes without major physical alterations. The paper trays should be as large as possible in order to save time replacing paper. Ink or toner cartridges should be easily obtainable from multiple sources and be simple to replace in the printer.

Recommendations for Firearms Discipline

Each individual Firearms Section within the RCMP Forensic Laboratory System has different needs and demands to-consider when choosing a digital imaging system. Many of the sections already possess or have access to computer components that are suitable for inclusion in a digital imaging system. Surplus items from other sections can also be obtained to supplement the construction of such a system. Actual recommendations for hardware and software for an individual section will depend on:

1. Local legal requirements and forensic examinations performed by the section
2. Local microscopic and related equipment in the section
3. Local computer hardware and software available for use by the section
4. Network system capability within the local laboratory
5. Presence of Photography/Imaging Section within the local laboratory
6. Computer hardware and software knowledge within the section

Legal requirements/Forensic Examinations

Each Firearms Section serves a unique region of Canada. Over the years each area has developed different requirements and expectations concerning the way evidence is collected, examined and presented in court. Photographs of exhibits are commonly entered as evidence in some jurisdictions, while in other areas, photographs are rarely used. This will influence the minimum quality of the output of the images by the section, and therefore the type of printer needed.

If crime scene analysis is included in an individual section's examinations, then a hand held digital camera will be needed to document locations and evidence. Also, if specialized examinations are conducted, such as GSR or speedometer work, then it would be advantageous for the related equipment to be capable of capturing digital images.

Local Microscopic and Related Equipment

The type of equipment within each individual Firearms Section will influence the overall makeup of their digital imaging system. All sections will need to connect their comparison microscopes to a camera/computer system to capture images of objects under examination. Each section is also equipped with a bore scope/CCD camera combination that can be connected to a video capture system, and the video camera components of the existing PhotoPhone system can also be used with any new digital equipment.

Any other related computer equipment, such as scanners, removable storage systems, printers, cameras, etc. within an individual section can also be easily integrated into a section digital imaging section as long as these pieces of hardware can work with the industry standard imaging file systems. Other local laboratory resources can also be used if they can be accessed via some mechanism for the capture, processing or output of images. If a local laboratory has a dedicated imaging section, images can be delivered via various methods for high quality output for court or lecture purposes. Theses files could also be sent to another laboratory via e-mail for further work there,

Computer Skills within the Local Section

The amount and type of computer skill and knowledge will have a great impact on the use of digital imaging equipment within a particular section. The best digital equipment available will sit idle if there is nobody with the knowledge or desire to use it, therefore, the proper training combined with suitable equipment is vital in order for the transition. The lack of interest, in learning this new technology, by section members can halt the process as quickly as not having the right equipment. In fact, it may be wiser to spend the money in other sections or other areas if no interest can be found at a particular location.

Hardware Options

The following are options for the movement of the firearms discipline to the capability of capturing, storing, managing, and outputting digital images:

Minimum configuration

80486 computer system, video camera with comparison microscope interface and Snappy image capture device and software.

Standard configuration

Pentium computer system with LAN connection, CCD video camera with magnification connection, PCI video capture card, flat bed scanner, Zip drive, Adobe Photoshop software on network.

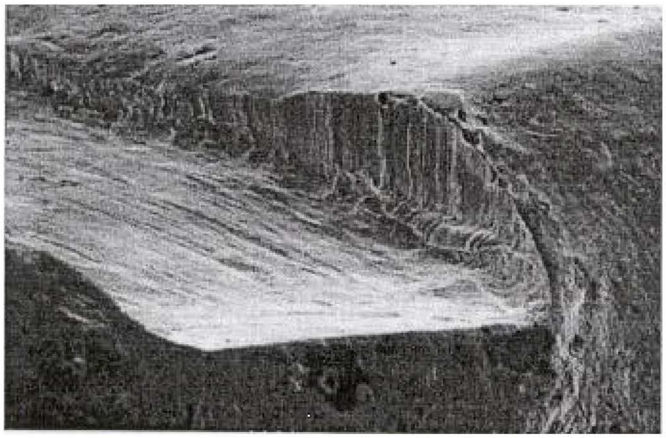
Optimal configuration

Pentium II computer system with LAN connection, PCI video capture card, CD Recorder, JAZ drive, film scanner, flat bed scanner, Zip drive, Adobe PHOTOSHOP software on local computer.

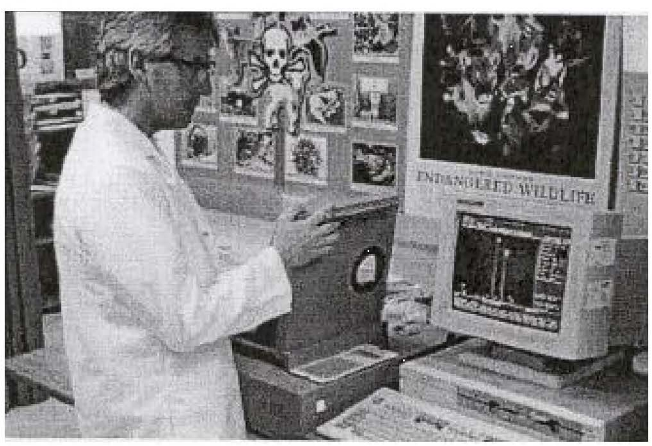
These configurations can be mixed and matched within the section and over time as resources allow and requirements or technologies change. Equivalent storage devices can also be added to these systems if they are made available by other areas.

Examples of Firearms Section Digital Images

Ruger 10/22 Firing Pin Impression taken with the Scanning Electron Microscope

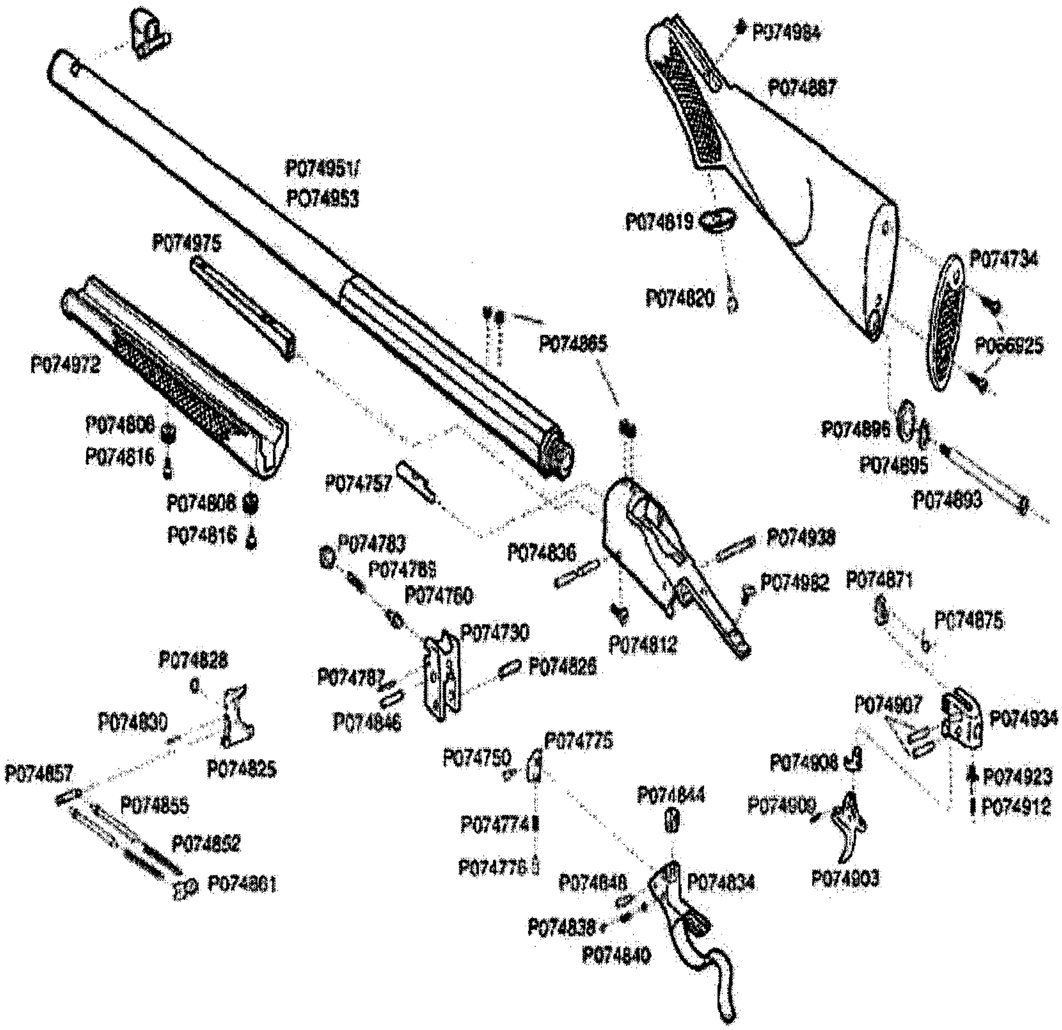


X-Ray Flourescence Machine (for shot composition determination) taken with a handheld camera

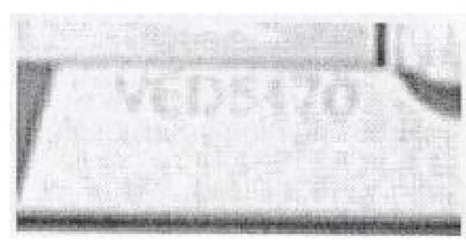


The above images courtesy of the US F&W National Laboratory

Exploded diagram of a Browning Model 1885 captured with a flat bed scanner



Images taken with a Nikon digital camera



Glossary

AGP - accelerated graphics port - new motherboard interface that is dedicated strictly for high performance 3D graphics applications,

Bit - Binary information a computer uses that is stored and read as a series of "zeros" and "ones".

Byte - An eight bit packet of information that a computer CPU processes as a fundamental unit. This measure is used to define storage space and memory capacity.

CD-ROM - Compact Disc Read Only Memory

CD-R - Compact Disc Recordable

CD-RW - Compact Disc Rewritable

CMYK - Cyan, magenta, yellow and black - subtractive primary colors

CPU - Central Processing Unit - The "brain" of the computer that is primarily responsible for running software commands.

DRAM - Dynamic Random Access Memory - A type of system memory packaging that can hold data for short periods of time before being refreshed.

DVD - Digital Video or Versatile Disk - Very high capacity form of Compact Disc

EIDE - Enhanced IDE interface

EDO - Extended Data Out - A form of DRAM that shortens the read time between the CPU and the memory by as much as 10 to 15 percent over conventional member.

Gigabyte - Approximately one billion bytes of information.

Kilobyte - Approximately one thousand bytes of information.

LAN - Local Area Network - connecting multiple users together for file, printing, e-mail, etc. sharing.

Megabyte - Approximately one million bytes of information.

Nanosecond - One billionth of a second. Memory data access speed is measured in nanoseconds.

SCSI - Small Computer System Interface - An physical interface that allows up to eight hardware devices to be linked together to a single controller in a computer.

SDRAM - Synchronous dynamic RAM - DRAM that uses a clock to synchronize signal input and output with the CPU clock to effectively increase the performance of their interaction.

SGRAM - Synchronous graphics RAM - single ported memory with bus speeds between 66 to 100 MHZ.

Session - A recorded segment of a compact disc that may contain one or more tracks of any type of data.

VRAM - video RAM - dual ported memory that allows both read and write operations at the same time.

WRAM - window RAM - high speed (50 MHZ) dual ported memory used with video cards requiring high resolution and color numbers.

WAN - Wide Area Network - usually connecting LANs at different locations together