A

Seminar report

On

NIGHT VISION TECHNOLOGY

Submitted in partial fulfillment of the requirement for the award of degree of Bachelor of Technology in Computer Science

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Acknowledgement

I would like to thank respected Mr…….. and Mr. ……..for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report. It helped me a lot to realize of what we study for.

Secondly, I would like to thank my parents who patiently helped me as i went through my work and helped to modify and eliminate some of the irrelevant or un-necessary stuffs.

Thirdly, I would like to thank my friends who helped me to make my work more organized and well-stacked till the end.

Next, I would thank Microsoft for developing such a wonderful tool like MS Word. It helped my work a lot to remain error-free.

Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

Preface

I have made this report file on the topic **NIGHT VISION TECHNOLOGY**; I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

INTRODUCTION

Night vision technology, by definition, literally allows one to see in the dark. Originally developed for military use, it has provided the United States with a strategic military advantage, the value of which can be measured in lives.

Federal and state agencies now routinely utilize the technology for site security, surveillance as well as search and rescue. Night vision equipment has evolved from bulky optical instruments in lightweight goggles through the advancement of image intensification technology.

TYPES OF NIGHT VISION

Night Vision technology is a term that presently encompasses three distinct technologies. The first night vision equipment was developed during the Korean War. Now sometimes referred to as generation-zero, this equipment employed image converter technology to transform infrared to visible light. The equipment operated in an active mode in that it required the subject of observation to be illuminated with an infrared light source. Lasers and filtered flashlights were utilized for this purpose. Resolution of the detector was constrained by the available processing technology at the time, limiting practical military engagement distances to within a few hundred meters. This active system also had the drawback of being easily detected by others with viewing equipment.

The subsequent principal technological development for night vision is thermal imaging. Thermal imagers are passive systems that respond to available infrared light at wavelengths in the 8-12 micrometer range. These wavelengths are readily emitted by all blooded animals as well as soil and plant life, warmed during the daytime hours. Infrared light is thus generated and available continuously, during both the day and night, so that these viewers have the distinction of performing equally well in both environmental lighting extremes.

The vast majority of night vision equipment and what most people think of when the are referring to ``Night Vision'' are devices that utilize image intensification technology. These devices are presently in their third development phase. They are passive devices that operate using naturally available light. Incoming light is converted to electrons, which are amplified and converted back into visible light.

HOW NIGHT VISION WORKS

The first thing you probably think of when you see the words **night vision** is a spy or action movie you've seen, in which someone straps on a pair of night-vision goggles to find someone else in a dark building on a moonless night. And you may have wondered "Do those things really work? Can you actually see in the dark?"

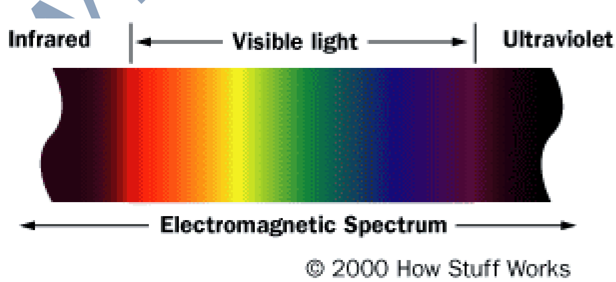
The answer is most definitely yes. With the proper night-vision equipment, you can see a person standing over 200 yards (183 m) away on a moonless, cloudy night! Night vision can work in two very different ways, depending on the technology used.

- **Image enhancement** - This works by collecting the tiny amounts of light, including the lower portion of the infrared light spectrum, that are present but may be imperceptible to our eyes, and amplifying it to the point that we can easily observe the image.
- **Thermal imaging** - This technology operates by capturing the upper portion of the infrared light spectrum, which is emitted as heat by objects instead of simply reflected as light. Hotter objects, such as warm bodies, emit more of this light than cooler objects like trees or buildings.

In this article, you will learn about the two major night-vision technologies. We'll also discuss the various types of night-vision equipment and applications. But first, let's talk about infrared light.

Infrared Light

In order to understand night vision, it is important to understand something about light. The amount of energy in a light wave is related to its wavelength: Shorter wavelengths have higher energy. Of visible light, violet has the most energy, and red has the least. Just next to the visible light spectrum is the **infrared** spectrum.



Infrared light is a small part of the light spectrum.

Infrared light can be split into three categories:

- **Near-infrared** (near-IR) - Closest to visible light, near-IR has wavelengths that range from 0.7 to 1.3 **microns**, or 700 billionths to 1,300 billionths of a meter.

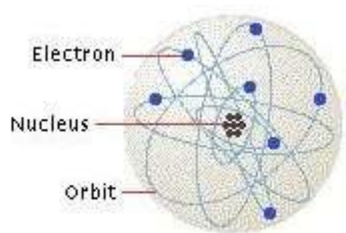
- **Mid-infrared** (mid-IR) - Mid-IR has wavelengths ranging from 1.3 to 3 microns. Both near-IR and mid-IR are used by a variety of electronic devices, including remote controls.
- **Thermal-infrared** (thermal-IR) - Occupying the largest part of the infrared spectrum, thermal-IR has wavelengths ranging from 3 microns to over 30 microns.

The key difference between thermal-IR and the other two is that thermal-IR is **emitted** by an object instead of reflected off it. Infrared light is emitted by an object because of what is happening at the **atomic** level.

Atoms

Atoms are constantly in motion. They continuously vibrate, move and rotate. Even the atoms that make up the chairs that we sit in are moving around. Solids are actually in motion! Atoms can be in different states of **excitation**. In other words, they can have different energies. If we apply a lot of energy to an atom, it can leave what is called the **ground-state energy level** and move to an **excited level**. The level of excitation depends on the amount of energy applied to the atom via heat, light or electricity.

An atom consists of a **nucleus** (containing the **protons** and **neutrons**) and an **electron cloud**. Think of the electrons in this cloud as circling the nucleus in many different **orbits**. Although more modern views of the atom do not depict discrete orbits for the electrons, it can be useful to think of these orbits as the different energy levels of the atom. In other words, if we apply some heat to an atom, we might expect that some of the electrons in the lower energy orbitals would transition to higher energy orbitals, moving farther from the nucleus.



An atom has a nucleus and an electron cloud.

Once an electron moves to a higher-energy orbit, it eventually wants to return to the ground state. When it does, it releases its energy as a **photon** -- a particle of light. You see atoms releasing energy as photons all the time. For example, when the heating element in a toaster turns bright red, the red color is caused by atoms excited by heat, releasing red photons. An excited electron has more energy than a relaxed electron, and just as the electron absorbed some amount of energy to reach this excited level, it can release this energy to return to the ground state. This emitted energy is in the form of photons (light energy). The photon emitted has a very specific wavelength (color) that depends on the state of the electron's energy when the photon is released.

Anything that is alive uses energy, and so do many inanimate items such as engines and rockets. Energy consumption generates heat. In turn, heat causes the atoms in an object to fire off photons in the thermal-infrared spectrum. The hotter the object, the shorter the wavelength of the infrared photon it releases. An object that is very hot will even begin to emit photons in the visible spectrum, glowing red and then moving up through orange, yellow, blue and eventually white. Be sure to read How Light Bulbs Work, How Lasers Work and How Light Works for more detailed information on light and photon emission.

In night vision, thermal imaging takes advantage of this infrared emission. In the next section, we'll see just how it does this.

Thermal Imaging

Here's how thermal imaging works:

1. A special lens focuses the infrared light emitted by all of the objects in view.
2. The focused light is scanned by a phased array of infrared-detector elements. The detector elements create a very detailed temperature pattern called a **thermogram**. It only takes about one-thirtieth of a second for the detector array to obtain the temperature information to make the thermogram. This information is obtained from several thousand points in the field of view of the detector array.
3. The thermogram created by the detector elements is translated into electric impulses.
4. The impulses are sent to a signal-processing unit, a circuit board with a dedicated chip that translates the information from the elements into data for the display.
5. The signal-processing unit sends the information to the display, where it appears as various colors depending on the intensity of the infrared emission. The combination of all the impulses from all of the elements creates the image.

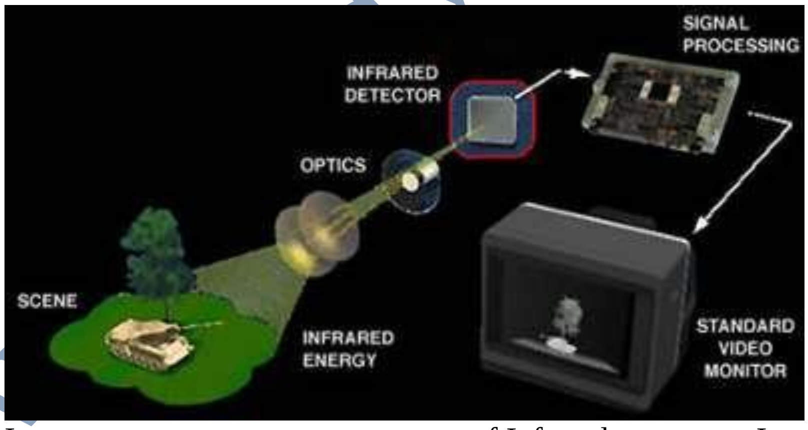


Image courtesy of Infrared, Inc.
The basic components of a thermal-imaging system

Types of Thermal Imaging Devices

Most thermal-imaging devices scan at a rate of 30 times per second. They can sense temperatures ranging from -4 degrees Fahrenheit (-20 degrees Celsius) to 3,600 F (2,000 C), and can normally detect changes in temperature of about 0.4 F (0.2 C).

Image courtesy of Infrared, Inc.
It is quite easy to see everything during the day...

Image courtesy of Infrared, Inc.
...but at night, you can see very little.

Image courtesy of Infrared, Inc.
Thermal imaging lets you see again.

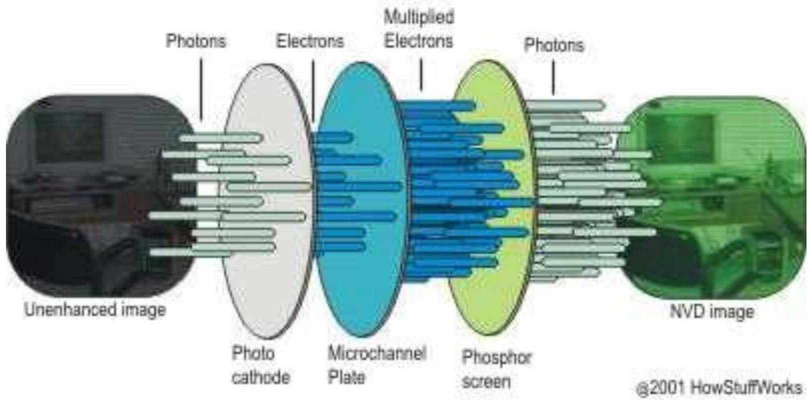
There are two common types of thermal-imaging devices:

- **Un-cooled** - This is the most common type of thermal-imaging device. The infrared-detector elements are contained in a unit that operates at room temperature. This type of system is completely quiet, activates immediately and has the battery built right in.
- **Cryogenically cooled** - More expensive and more susceptible to damage from rugged use, these systems have the elements sealed inside a container that cools them to below 32 F (zero C). The advantage of such a system is the incredible resolution and sensitivity that result from cooling the elements. Cryogenically-cooled systems can "see" a difference as small as 0.2 F (0.1 C) from more than 1,000 ft (300 m) away, which is enough to tell if a person is holding a gun at that distance!

While thermal imaging is great for detecting people or working in near-absolute darkness, most night-vision equipment uses image-enhancement technology.

Image Enhancement

Image-enhancement technology is what most people think of when you talk about night vision. In fact, image-enhancement systems are normally called **night-vision devices** (NVDs). NVDs rely on a special tube, called an **image-intensifier tube**, to collect and amplify infrared and visible light.



The image-intensifier tube changes photons to electrons and back again.

Here's how image enhancement works:

1. A conventional lens, called the **objective lens**, captures ambient light and some near-infrared light.
2. The gathered light is sent to the image-intensifier tube. In most NVDs, the power supply for the image-intensifier tube receives power from two N-Cell or two "AA" batteries. The tube outputs a high voltage, about 5,000 volts, to the image-tube components.
3. The image-intensifier tube has a **photocathode**, which is used to convert the photons of light energy into electrons.
4. As the electrons pass through the tube, similar electrons are released from atoms in the tube, multiplying the original number of electrons by a factor of thousands through the use of a **microchannel plate** (MCP) in the tube. An MCP is a tiny glass disc that has millions of microscopic holes (microchannels) in it, made using fiber-optic technology. The MCP is contained in a vacuum and has metal electrodes on either side of the disc. Each channel is about 45 times longer than it is wide, and it works as an electron multiplier.

   When the electrons from the photo cathode hit the first electrode of the MCP, they are accelerated into the glass microchannels by the 5,000-V bursts being sent between the electrode pair. As electrons pass through the microchannels, they cause thousands of other electrons to be released in each channel using a process called **cascaded secondary emission**. Basically, the original electrons collide with the side of the channel, exciting atoms and causing other electrons to be released. These new electrons also collide with other atoms, creating a chain reaction that results in thousands of electrons leaving the channel where only a few entered. An interesting fact is that the microchannels in the MCP are created at a slight angle (about a 5-degree to 8-degree bias) to encourage electron collisions and reduce both ion and direct-light feedback from the phosphors on the output side.

5. At the end of the image-intensifier tube, the electrons hit a screen coated with phosphors. These electrons maintain their position in relation to the channel they passed through, which provides a perfect image since the electrons stay in the same alignment as the original photons. The energy of the electrons causes the phosphors to reach an excited state and release photons. These phosphors create the green image on the screen that has come to characterize night vision.
6. The green phosphor image is viewed through another lens, called the **ocular lens**, which allows you to magnify and focus the image. The NVD may be connected to an electronic display, such as a monitor, or the image may be viewed directly through the ocular lens.

Photo courtesy of B.E. Meyers Company
Night-vision images are known for their eerie green tint.

GENERATIONS

NVDs have been around for more than 40 years. They are categorized by **generation**. Each substantial change in NVD technology establishes a new generation.

- **Generation 0** - The original night-vision system created by the United States Army and used in World War II and the Korean War, these NVDs use **active infrared**. This means that a projection unit, called an **IR Illuminator**, is attached to the NVD. The unit projects a beam of near-infrared light, similar to the beam of a normal flashlight. Invisible to the naked eye, this beam reflects off objects and bounces back to the lens of the NVD. These systems use an anode in conjunction with the cathode to accelerate the electrons. The problem with that approach is that the acceleration of the electrons distorts the image and greatly decreases the life of the tube. Another major problem with this technology in its original military use was that it was quickly duplicated by hostile nations, which allowed enemy soldiers to use their own NVDs to see the infrared beam projected by the device.

- **Generation 1** - The next generation of NVDs moved away from active infrared, using**passive infrared** instead. Once dubbed **Starlight** by the U.S. Army, these NVDs use ambient light provided by the moon and stars to augment the normal amounts of reflected infrared in the environment. This means that they did not require a source of projected infrared light. This also means that they do not work very well on cloudy or moonless nights. Generation-1 NVDs use the same image-intensifier tube technology as Generation 0, with both cathode and anode, so image distortion and short tube life are still a problem.

- **Generation 2** - Major improvements in image-intensifier tubes resulted in Generation-2 NVDs. They offer improved resolution and performance over Generation-1 devices, and are considerably more reliable. The biggest gain in Generation 2 is the ability to see in extremely low light conditions, such as a moonless night. This increased sensitivity is due to the addition of the microchannel plate to the image-intensifier tube. Since the MCP actually increases the number of electrons instead of just accelerating the original ones, the images are significantly less distorted and brighter than earlier-generation NVDs.

- **Generation 3** - Generation 3 is currently used by the U.S. military. While there are no substantial changes in the underlying technology from Generation 2, these NVDs have even better resolution and sensitivity. This is because the photo cathode is made using **gallium arsenide**, which is very efficient at converting photons to electrons. Additionally, the MCP is coated with an ion barrier, which dramatically increases the life of the tube.

- **Generation 4** - What is generally known as Generation 4 or "filmless and gated" technology shows significant overall improvement in both low- and high-level light environments.
  The removal of the ion barrier from the MCP that was added in Generation 3 technology reduces the background noise and thereby enhances the signal to noise ratio. Removing the ion film actually allows more electrons to reach the amplification stage so that the images are significantly less distorted and brighter.

  The addition of an automatic gated power supply system allows the photocathode voltage to switch on and off rapidly, thereby enabling the NVD to respond to a fluctuation in lighting conditions in an instant. This capability is a critical advance in NVD systems, in that it allows the NVD user to quickly move from high-light to low-light (or from low-light to high-light) environments without any halting effects. For example, consider the ubiquitous movie scene where an agent using night vision goggles is “sightless” when someone turns on a light nearby. With the new, gated power feature, the change in lighting wouldn’t have the same impact; the improved NVD would respond immediately to the lighting change.

Many of the so-called "bargain" night-vision scopes use Generation-0 or Generation-1 technology, and may be disappointing if you expect the sensitivity of the devices used by professionals. Generation-2, Generation-3 and Generation 4 NVDs are typically expensive to purchase, but they will last if properly cared for. Also, any NVD can benefit from the use of an IR Illuminator in very dark areas where there is almost no ambient light to collect.

Photo courtesy of B.E. Meyers Company
NVDs come in a variety of styles, including ones that can be mounted to cameras.

A cool thing to note is that every single image-intensifier tube is put through rigorous tests to see if it meets the requirements set forth by the military. Tubes that do are classified as **MILSPEC**. Tubes that fail to meet military requirements in even a single category are classified as **COMSPEC**.

NIGHT VISION EQUIPMENT AND APPLICATIONS

Night-vision equipment can be split into three broad categories:

- **Scopes** - Normally handheld or mounted on a weapon, scopes are **monocular** (one eye-piece). Since scopes are handheld, not worn like goggles, they are good for when you want to get a better look at a specific object and then return to normal viewing conditions.

Photo courtesy of B.E. Meyers Company
DARK INVADER Multi-purpose Pocketscope

- **Goggles** - While goggles can be handheld, they are most often worn on the head. Goggles are **binocular** (two eye-pieces) and may have a single lens or stereo lens, depending on the model. Goggles are excellent for constant viewing, such as moving around in a dark building.

Photo courtesy of B.E. Meyers Company
DARK INVADER Night-vision Goggles 4501

- **Cameras** - Cameras with night-vision technology can send the image to a monitor for display or to a VCR for recording. When night-vision capability is desired in a permanent location, such as on a building or as part of the equipment in a helicopter, cameras are used. Many of the newer camcorders have night vision built right in.

Photo courtesy of B.E. Meyers Company
Stealth 301 Series Day/Night Video Camera

APPLICATIONS

Common applications for night vision include:

- Military
- Law enforcement
- Hunting
- Wildlife observation
- Surveillance
- Security
- Navigation
- Hidden-object detection
- Entertainment

Photo courtesy of B.E. Meyers Company
This soldier is using DARK INVADER night-vision goggles.

The original purpose of night vision was to locate enemy targets at night. It is still used extensively by the military for that purpose, as well as for navigation, surveillance and targeting.

Police and security often use both thermal-imaging and image-enhancement technology, particularly for surveillance. Hunters and nature enthusiasts use NVDs to maneuver through the woods at night.

Detectives and private investigators use night vision to watch people they are assigned to track. Many businesses have permanently-mounted cameras equipped with night vision to monitor the surroundings.

A really amazing ability of thermal imaging is that it reveals whether an area has been disturbed -- it can show that the ground has been dug up to bury something, even if there is no obvious sign to the naked eye. Law enforcement has used this to discover items that have been hidden by criminals, including money, drugs and bodies. Also, recent changes to areas such as walls can be seen using thermal imaging, which has provided important clues in several cases.

Photo courtesy of B.E. Meyers Company
Camcorders are a fast-growing segment of the night-vision industry.

Many people are beginning to discover the unique world that can be found after darkness falls. If you're out camping or hunting a lot, chances are that night-vision devices can be useful to you -- just be sure to get the right type for your needs.

TECHNICAL CHARACTERISTICS OF NIGHT VISION

Using intensified night vision is different from using regular binoculars and/or your own eyes. Below are some of the aspects of night vision that you should be aware of when you are using an image intensified night vision system.

Textures, Light and Dark

Objects that appear light during the day but have a dull surface may appear darker through the night vision unit than objects that are dark during the day but have a highly reflective surface. For example, a shiny, dark-colored jacket may appear brighter than a light-colored jacket with a dull surface.

Depth Perception

Night vision does not present normal depth perception.

Fog and Rain

Night vision is very responsive to reflective ambient light; therefore, the light reflecting off of fog or heavy rain causes much more light to go toward the night vision unit and may degrade its performance. However, advances in the latest night vision help offset these effects.

Honeycomb*

Honeycomb is a faint hexagonal pattern, which is the result of the manufacturing process.

Spots*

A few black spots throughout the image area also are inherent characteristics of all night vision technology. These spots will not increase in size or number.

* Do not be concerned if you see this feature. It is an inherent characteristic found in light amplification night vision systems that incorporate a microchannel plate in the intensifier.

CONCLUSION

Although the term ``night vision" currently encompasses three distinct technologies, it is the evolution of image intensification technology that first made devices practical and widely used. Their success was the result of advancements in light amplification and resolution techniques.

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