

AD-A088 165

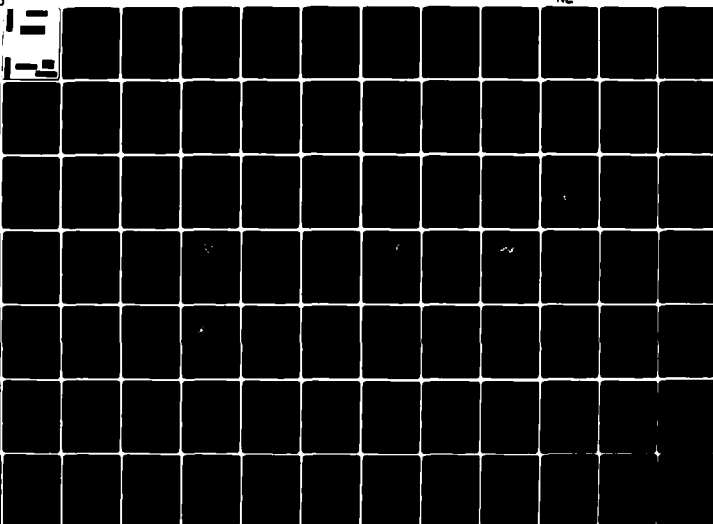
ARMY MILITARY PERSONNEL CENTER ALEXANDRIA VA
APPLICATION OF IMAGE INTENSIFIER TECHNOLOGY TO THE MILITARY, SC--ETC(U)
MAY 80 P H ORELL

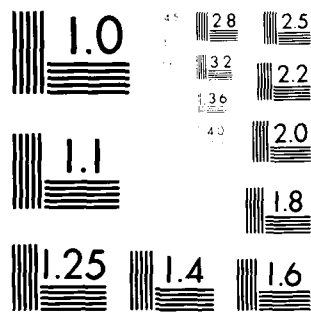
F/G 9/1

UNCLASSIFIED

NL

1 of 2
200-117





MICROCOPY RESOLUTION TEST CHART
 NATIONAL BUREAU OF STANDARDS-1963-A

21

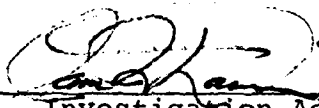
6 APPLICATION OF IMAGE INTENSIFIER TECHNOLOGY
TO THE MILITARY, SCIENTIFIC, INDUSTRIAL,
EDUCATIONAL, AND MEDICAL COMMUNITIES.

by
10 Patrick H. Orell

12 99

9 Final rept.
A Research Paper

Submitted to Complete the
Plan B Requirements in
600-722
Problems in Audio-Visual Communications


Investigation Adviser

The Graduate College
University of Wisconsin-Stout
11 34 May 1980

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution unlimited

391191 - Gu

A

UNCLASSIFIED SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
AD-A088165		
4. TITLE (and Subtitle) APPLICATION OF IMAGE INTENSIFIER TECHNOLOGY TO THE MILITARY, SCIENTIFIC, INDUSTRIAL, EDUCATIONAL, AND MEDICAL COMMUNITIES		5. TYPE OF REPORT & PERIOD COVERED Final Report Approved 30 May 1980
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Patrick H. Orell		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Student HQDA, MILPERCEN, (DAPC-OPP-E) 200 Stovall Street Alexandria, VA 22332		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS HQDA, MILPERCEN ATTN: DAPC-OPP-E 200 Stovall Street Alexandria, VA 22332		12. REPORT DATE 30 May 1980
		13. NUMBER OF PAGES 87
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES A thesis submitted to Graduate College, University of Wisconsin - STOUT, Monomonic, Wisconsin 54751, in partial fulfillment of the requirements for the degree of MS in Media Technology.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) 1st and second generation Image Intensifiers, scopes, low light level television tubes, and charge coupled devices, applications and uses.		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This research paper addresses the applications of Image Intensifier technology to the Military, Scientific, Industrial, Educational and Medical communities. Image intensifiers are components, that when incorporated into scopes, photographic cameras, television cameras and weapons delivery systems, allow the operator visibility into dark or low illumination areas. The technology has surfaced within the last twenty years and has been, until recently, confined to the		

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Item 20 Continued

military for applications. Image intensified devices are rapidly becoming more popular for various applications, yet many persons are not aware of their existence or potential. The paper is written in non-technical terms to describe the physical make-up of first and second generation Image Intensifiers and addresses the newly developed charged coupled devices and third generation intensifiers under development. It covers a representative sample of applications that have been documented to date by the various manufacturers of Image Intensifiers and the laboratories and agencies that evaluate them. The paper incorporates 37 photographs and illustrations of devices and their applications in support of the communities listed. A list of documented applications and an Image Intensifier tube sensitivity chart is provided for information and reference.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

APPLICATION OF IMAGE INTENSIFIER TECHNOLOGY TO THE MILITARY, SCIENTIFIC,
INDUSTRIAL, EDUCATIONAL, AND MEDICAL COMMUNITIES

Patrick H. Orell, O-4
HQDA, MILPERCEN (DAPC-OPP-E)
200 Stovall Street
Alexandria, VA 22332

Final Report approved 30 May 1980

Approved for public release; distribution unlimited.

A thesis submitted to Graduate College, University of Wisconsin - STOUT,
Menomonie, Wisconsin 54751, in partial fulfillment of the requirements
for the degree of MS in Media Technology.

A

The Graduate College
University of Wisconsin-Stout
Menomonie, Wisconsin 54751

ABSTRACT

	Orell	Patrick	H.
(Writer)	(Last Name)	(First)	(Initial)

Application of Image Intensifier Technology To The Military,
(Title)

Scientific, Industrial, Educational, and Medical Communities

Media Technology	Dr. James Daines	May, 1980	87
(Graduate Major)	(Research Adviser)	(Month/Year)	(No. of Pages)

This research paper addresses the applications of Image Intensifier technology to the Military, Scientific, Industrial, Educational and Medical communities. Image intensifiers are components, that when incorporated into scopes, photographic cameras, television cameras and weapons delivery systems, allow the operator visibility into dark or low illumination areas. The technology has surfaced within the last twenty years and has been, until recently, confined to the military for applications. Image intensified devices are rapidly becoming more popular for various applications, yet many persons are not aware of their existence or potential. The paper is written in non-technical terms to describe the physical make-up of first and second generation Image Intensifiers and addresses the newly developed charged coupled devices and third generation intensifiers under development. It covers a representative sample of applications that have been documented to date by the various manufacturers of Image Intensifiers and the laboratories and agencies that evaluate them. The paper incorporates 37 photographs and illustrations of devices and their applications in support of the communities listed. A list of documented applications and an Image Intensifier tube sensitivity chart is provided for information and reference.

- 2 -

ACKNOWLEDGEMENTS

The writer of this study wishes to express his appreciation to the following people: Mr. Richard Franseen for his assistance in identifying manufacturers; Dr. James Daines for his assistance as investigation advisor; Mrs. Margy Ingram and Mr. Bob Ward for assistance with photo preparation; Dr. Tom Franklin for his assistance; and his family for their patience and support.

Patrick H. Orell

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	ii
LIST OF TABLES	v
LIST OF FIGURES	vi
 Chapter	
1. INTRODUCTION TO THE STUDY	1
Statement of the Problem	3
Purpose of the Study	3
Method of the Study	4
Scope and Limitations	5
Definition of Terms	5
2. REVIEW OF LITERATURE	7
First Generation Image Intensifier	10
Second Generation Image Intensifier	15
3. RESEARCH PROCEDURES	19
Subjects	19
Method of Study	20
Interview Procedures	21
Limitations	21
Method of Analysis	22
4. RESULTS	23
Applications: First Generation Devices	23
Military Applications	23

Chapter	Page
Educational Applications	29
Industrial Applications	31
Scientific Applications	33
Applications: Second Generation Devices . . .	35
Military Applications	35
Educational Applications	45
Industrial Applications	53
Science and Medical Applications	60
New Developments	67
5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS	77
Summary	77
Conclusions	78
Recommendations	79
Recommendations for Further Study	80
BIBLIOGRAPHY	81
APPENDICES	
Appendix A	86
Appendix B	87

LIST OF TABLES

Table	Page
1. Types of Applications	73
2. Image Tube Sensitivity	75

LIST OF FIGURES*

Figure	Page
1. The Electronic Spectrum (NVL)	8
2. First Generation Single Stage Image Intensifier (RCA)	11
3. Three-Stage First Generation, Image Intensifier (VARO)	13
4. Microchannel Plate Performance Illustration (LITTON)	16
5. Second Generation Microchannel Plate Image Intensifier (VARO)	17
6. First Generation Rifle Scope Sight (NVL)	24
7. First Generation Crew Served Weapon Scope Sight (NVL)	25
8. Iroquois Night Fighter and Night Tracker (U.S. Army)	26
9. Aircraft Target Detection System (WESTINGHOUSE) .	29
10. TV Microscopy (COHU)	30
11. Environmentally Housed Security Camera (COHU) . .	33
12. Apollo Lunar Camera (WESTINGHOUSE)	34
13. Apollo Color Camera (WESTINGHOUSE)	35
14. Second Generation Rifle Sight Scope (NVL)	36
15. Second Generation Crew Served Weapon Sight (NVL)	37
16. Second Generation Driver Viewer (NVL)	38
17. Night Vision Goggles (LITTON)	39
18. Night Vision Goggles, Driver Application (LITTON)	40

Figure	Page
19. Night Vision Goggles, Weapon Aiming Application (NVL)	41
20. Light Level Chart (COHU)	42
21. Deep Submergence Rescue Vehicle (COHU)	44
22. Laser Designator (MARTIN MARIETTA AEROSPACE)	45
23. Fluoroscope With Interfaced LLLTV Camera (COHU)	47
24. "Cyclops" Night Vision Goggles (VARO)	48
25. Army LLLTV System For Training Evaluation (U.S. ARMY)	51
26. Nuclear Reactor Inspection (COHU)	54
27. Welding Inspection (EDO WESTERN)	55
28. Oil Well Re-Entry System (EDO-WESTERN)	57
29. Oil Drilling Casing Inspection (COHU)	58
30. Noctron IV Night Viewer (VARO)	60
31. Underwater TV System (EDO WESTERN)	62
32. Underwater TV Image (EDO WESTERN)	62
33. Rocket Engine Testing (COHU)	63
34. Charge Coupled Device (FAIRCHILD)	68
35. Cockpit Television Sensors (FAIRCHILD)	70
36. Artillery Application (FAIRCHILD)	71
37. Artillery-Launched TV Package (FAIRCHILD)	71

* This list of figures is to not only show the location of each figure, but to also credit the source of each. The source will be shown in the parenthesis.

Chapter 1

INTRODUCTION TO THE STUDY

Man's inability to see in low illumination areas has always limited his ability to function during the hours of darkness. History shows us that this was especially true for men in military combat. There have been numerous successful night raids and ambush techniques recorded, but all had problems with the darkness. The most prevalent was the inability of the soldier to see either his comrades or the enemy. Because of this, night fighting has been successful only for those who are well organized and very knowledgeable of the terrain on which they are maneuvering.

The United States Army began experimenting with night vision devices during World War II in hope of solving this difficulty. They began by introducing a device that would allow them to illuminate an object or area, without being detected by the naked eye. They accomplished this by using the near infra-red wavelength of light. This spectrum is invisible to the naked eye, yet can be seen when viewing through a near infra-red viewing device, called a metascope. The army procured large numbers of infra-red lights and metascopes for use in night operations and used them with some success during the Korean conflict.

As the years passed, and technology throughout the world improved, near infra-red was being used by not only the United States and its allies, but by most enemies. This fact caused the application techniques of near infra-red illumination to change. It was quickly assumed that to use your near infra-red light to illuminate the battlefield was almost as dangerous as using "white" visible light, because the enemy would use his metascope to locate the position of the emitter. This fact caused interest in and usage of the lights to lessen, and interest in new technology to accelerate.

In the early 60's the Vietnam War was beginning and the night vision requirement was again a high priority to the United States. It seemed that the enemy in Vietnam was not equipped with metascopes, so the near infra-red systems met with success. One must remember however, that the devices were old, rather large and bulky, and certainly not designed for the type of usage the Vietnam war required. This war required a lightweight, sturdy, low power consumption device that could be made small enough to be efficiently used as a rifle scope. Unfortunately, none of the infra-red devices available in the early 60's could meet that requirement.

Statement of the Problem

In 1965 a new device was introduced by the U.S. Army Electronics Research and Development Command, Night Vision and Electro-Optics Laboratory called the "starlight" scope. This device was compact, passive, and could improve visibility during periods of low light levels of illumination by amplifying the point moon (moonlight) and starlight reflections illuminating a given area. It could also be used with the old near infra-red search light. This new capability was a major breakthrough in night vision technology and was due to the introduction of a component called the Image Intensifier.¹ Image intensifiers are becoming common and are being evaluated by the Army as a means of controlling and evaluating night training. The basic make-up of the devices evaluated and the application of these devices are not known by many in the education and media field.

Purpose of the Study

The purpose of this study was to report on the past and present applications of image intensifiers and low light level television hardware in the support of industry, science education, medicine and the military.

¹U.S. Army Electronics Research and Development Command Night Vision and Electro-Optics Laboratory Report, Night Vision (1979), p. 7.

Applications to broadcast equipment used by networks and stations will not be addressed.

Method of Study

The study took into consideration these sources of information: (1) A review of the literature pertinent to the problem, (2) Data furnished by the U.S. Army Electronics Research and Development Command Night Vision and Electro-Optics Laboratory (NVL), (3) Data from the companies that manufacture image intensification devices, and (4) The author's experience.

NVL and the 11 companies who manufacture the devices were contacted by telephone requesting any articles, brochures, or personal experience notes about applications of image intensifier technology to industry, science, education, medicine, and the military. All 11 companies responded, as did NVL, a return rate of 100 percent. The data received were compiled and displayed on a comparison chart to show the type of devices that are presently being produced. The chart allowed comparison of each device and its sensitivity to natural light sources (i.e., full sunlight, overcast day, twilight, full moon, overcast night, and clear starlight).

These data make an excellent quick reference, and were studied to make a conclusion about the future utility and diversity of image intensifier technology.

Scope and Limitations

Though there has been a great deal of work done in the area of image intensification, little of the success has been actively publicized. This has been due, in part, to the fact that most of the early applications were for the military, and those applications that were being used on the civilian market were limited to broadcasting, security, and surveillance work. Additionally, the technology is new, expensive, and just beginning to become known to potential users.

The information discussed in this study about military applications comes from company brochures and non-confidential evaluation reports supplied by the agencies referenced.

Definition of Terms

The following terms have been defined for the purpose of this study:

1. Fiber Optic: Slender filaments of plastic or glass that are molded together to form a solid optical tube. This tubing is cut into wafers and used in image intensifiers for coupling them together, and for image transfer in place of glass or mica plates.
2. Image Intensifier: A device that improves visibility during periods of low light levels by amplifying the

visible light, faint moon, or starlight reflections illuminating a given area.

3. Low Light Level Television: A television camera that operates in areas of low illumination or darkness.
4. Metascope: A vision device for observation of action in the near infrared light spectrum. Looks like half of a pair of binoculars.
5. Photocathode: The component in an imaging tube that converts the visual image being received into an electronic one.
6. Coupling: The bonding together of two or more items.
7. Blooming: The spreading of bright highlights into adjacent areas of a televised scene.
8. Cascaded Secondary Emission: The process where single electrons are multiplied thousands of times as they pass through an electronic component.

Chapter 2

REVIEW OF LITERATURE

To enhance the understanding of image intensifiers, one must know where in the electro magnetic spectrum they are effective. All image intensifiers have a sensitivity to certain areas of the light frequency spectrum or the wavelength ranges of electromagnetic radiation. This makes them similar to a radio receiver which is selectively tuned within the broad spectrum of electromagnetic energy. The human eye can see visible light, which falls in the wavelength range of between 0.4 and 0.7 microns. This occurs normally, to those who are not blind, and is sensed as visible illumination. When the 0.4 to 0.7 micron range is present, the eye adjusts to it, and the person is rewarded with the ability to see his surroundings. For a person to be able to see or sense his surroundings in the wavelengths above and below the visible light range, a detecting system is required. See Figure 1.

As is shown in Figure 1, there are many distinct areas to be detected, and specific devices for each area. This paper addresses only those devices called image intensifiers, which operate in the wavelength range of .4 to 3 microns. This wavelength range of light is commonly

referred to as visible and near infra-red.²

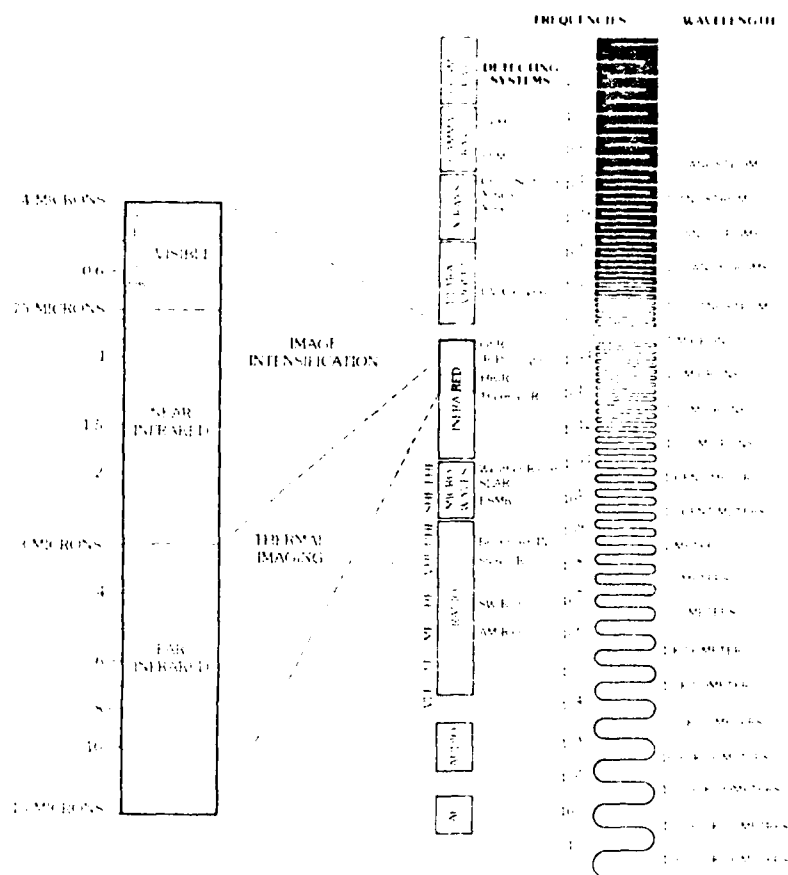


Figure 1

The Electronic Spectrum (NVL)

There are two categories of devices that have immersed successfully from the work in image intensification. They are night vision scopes and low light level television cameras. Both offer the user the capability of viewing into the .4 to 3 micron wavelength range passively, which means

²Ibid., p. 6.

without the need for active illumination assistance in the form of spotlights, searchlights, or flares. This passive capability is what has made the two categories so successful.

As stated in the introduction, the term image intensifier became famous when it was introduced as part of a night vision scope by NVL. This was actually a refined component that has been traced back to 1944 when the image orthicon (IO) camera tube was developed by RCA. The purpose of this tube was to add an electron gain to the image being received, thus allowing the television camera user to apply less light to the subject being viewed by the camera. In effect, this was the first image intensification device. These early tubes would produce an electron gain of three to four to the incoming light, making them effective for live pick ups in the studio and outdoor broadcast television camera applications.

In 1957, General Electric developed an image orthicon tube which would give an electron gain 10 times that of the incoming light. This was a great improvement, but these early tubes had a principal deficiency called image retention or lag. Lag has always been a problem with television tubes, and is seen even today with sophisticated television cameras when they pan through a light or the sun, leaving streak trails behind the light source that remains there long enough to be recognized. This trail is referred to by many as streaking. Television camera tubes are compared to each

other by many factors, but lag and the ability to keep streaking to a minimum, is a key factor.³

First Generation Image Intensifier

In an attempt to improve upon earlier tube technology, a very sensitive tube was introduced in the late 1950's that incorporated an image intensifier stage inside the television tube. This gave an increased electron gain capability of 30 to 40 times the incoming light, but they were extremely difficult to manufacture. Due to the manufacturing difficulties, they were replaced in the early 60's with a tube that had a first generation single stage image intensifier tube optically coupled to the front of the image orthicon tube.⁴ This first generation single stage image intensifier tube was a major breakthrough in the technology. (See Figure 2)

In the first generation single stage tube, the low light level image impacts the fiber optic faceplate. The image is coming from the optic attached to the device the tube is being used in, so the image is inverted by that optic before it impacts the faceplate (see arrows Figure 2). The faceplate transmits the image to the photocathode, where

³James E. Holthaus and James Meacham, LLTV (New York: Westinghouse Defense and Space Center, Aerospace Division, 1969), p. 1.

⁴Ibid.

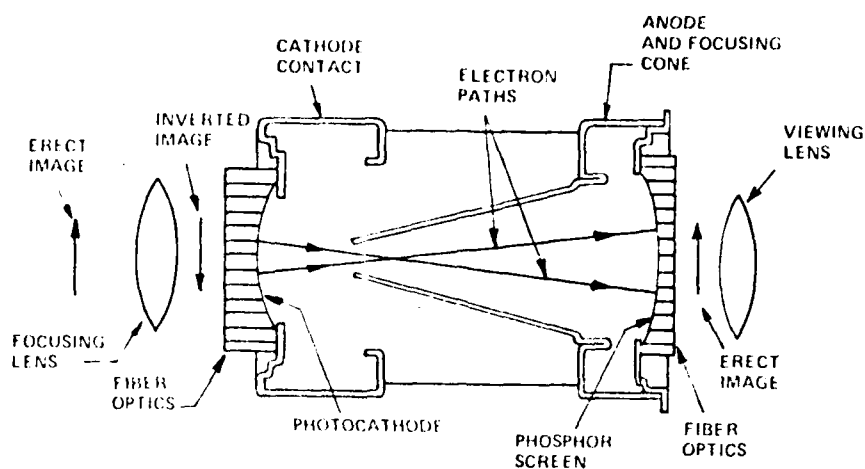


Figure 2

First Generation Single Stage
Image Intensifier (RCA)

the image is converted into an electronic one. The electronic image is accelerated toward the phosphor screen as it passes through the anode and focusing cone. Actual image intensification takes place during this passage through the anode and focusing cone, and the image is inverted again so that an erect amplified image strikes the phosphor screen. Electron gains in the single stage tube are in the order of 50-100.⁵

These first generation image intensifiers were described as "Single-Stage Fiber Optically Coupled, Electrostatic Image Intensifiers" and became available for use

⁵RCA, Imaging Devices IMD-100 (Lancaster, Pa.: RCA Solid State Division, Electro Optics Marketing, 1979), p. 5.

economically as image preamplifiers for camera tubes. To insure a quality performance with the device, it was coupled to the faceplate of the image orthicon camera tube. In order for this coupling to take place, the image orthicon tube was changed in its physical makeup from having a glass faceplate to having a fiber optic one. By changing to the fiber optic faceplate, the two tubes were both matched on their surfaces and could be bonded together. This connection is called coupling, and by inverting either the intensifier tube or the camera tube, one could compensate for the image inversion. This coupling technique was attempted using conventional optics instead of fiber optics, but the efficiency loss was severe.⁶

The coupling technique was a very sound method of achieving low light level performance and it was found that this performance was greatly increased by coupling three image intensifiers end to end. This device is called a Three-Stage First Generation, Image Intensifier Tube.

(See Figure 3)

The three stage tube was introduced in two types, electrostatically focused and magnetically focused.

Electrostatically focused imaging tubes are easily operated. They require an optical lens attached to the scene input end which accomplishes the focusing of the image

⁶Ibid.

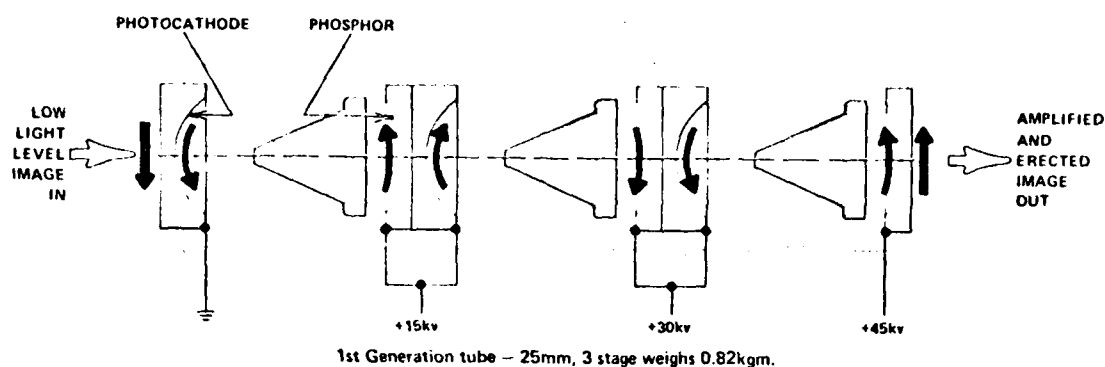


Figure 3

Three-Stage First Generation, Image Intensifier (VARO)

on the photocathode. They require an ocular at the image output end to allow viewing of the image after intensification, and a power supply for operation. The tube uses fiber optic faceplates to assist in controlling the fall off in image resolution toward the edge of the tube, and also to function as image transporters. This type tube operates on low voltage and is used with television cameras and scopes.

Magnetically focused imaging tubes combine the electrostatically produced field with the magnetic field (axial) which is induced by solenoid or a permanent magnet. By using a magnetic field that is virtually uniform throughout the tube, resolution is good across the surface of the third screen and little distortion is produced. The coupling is accomplished by using thin mica or the same fiber-optic as the electrostatic type. Both of these materials fulfill

the same requirements of controlling fall off in image resolution toward the edge of the tube, and function as image transporters. This type tube operates on higher voltage and is often used with photography equipment where controls are required to prevent excessive fogging of film during long exposures.⁷

Closely behind the introduction of the image intensifier came the introduction of a new television camera tube at Westinghouse called the Secondary Electron Conduction vidicon tube (SEC). The SEC tube, even without an intensifier attached, gave an electron gain of approximately 150. The SEC tube also exhibited low lag and had desirable image motion characteristics. When coupled with an image intensifier the tube configuration yielded a sensor that was comparable to the intensified image orthicon tubes (IIO), and with lower lag, better low contrast performance, less critical adjustments and "Hands-Off" operation. These tubes are called ISEC tubes and their capability and features made them a more desirable sensor than the IIO for military applications.⁸

The first generation tube was impressive, in either configuration (IIO or ISEC) and offered the television industry a new (television) capability, and the military a

⁷Ibid., p. 35.

⁸Holthaus and Meacham, op. cit., p. 2.

passive device for viewing the battlefield. The majority of the devices introduced in the mid 60's to early 70's were for the Army and were in the form of rifle scopes and crew served weapons' scopes. Both made use of the electrostatic type image intensifier.

Second Generation Devices

The 70's was a very successful decade for image intensification technology. It did not just appear over the horizon like sunlight at dawn, but it had come a long way in a very short period of time. The space program and the Vietnam war had accelerated it, plus new applications to education, science, medicine, and industry. All these potential users were in need of lightweight, high resolution, high luminous electron gain, low power operation devices. These needs and breakthroughs in electronics technology called integrated circuitry spurred the advent of a new image intensifier configuration called Second Generation Micro-channel Plate Image Intensifiers. These second generation intensifiers incorporate a new device called a microchannel plate (MCP). (See Figure 4)

The MCP is a disc shaped electron multiplier. Single electrons striking the input of the MCP are multiplied thousands of times through a process called cascaded secondary emission.

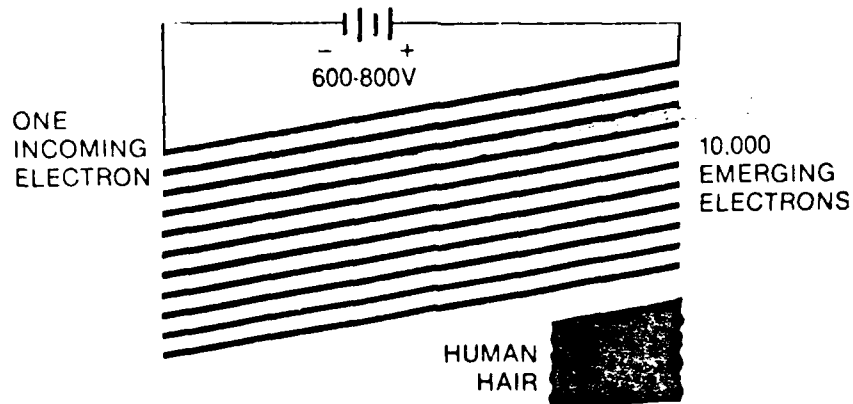


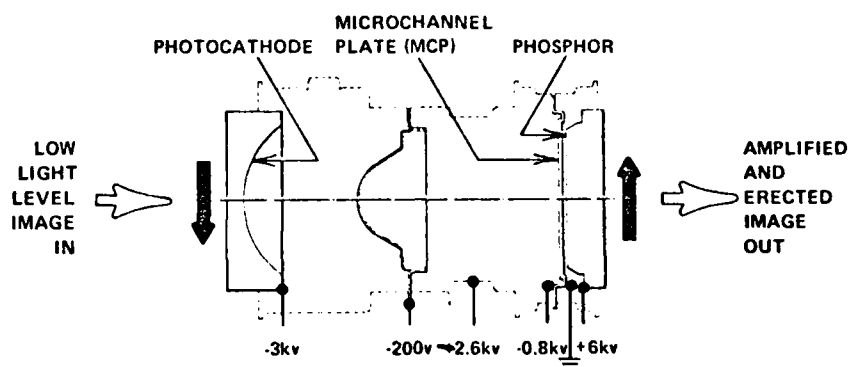
Figure 4

Microchannel Plate Performance
Illustration (LITTON)

The MCP consists of millions of microscopic channels or tubes that are fused together into a conducting disc shaped array. These tubes are much finer than a human hair and because each microscopic channel represents a separate high gain electron multiplier, the MCP is an excellent imaging electron multiplier. Because of the tubed channels, perfect position registration is also present between the input and output faces of the MCP for each channel. A disc, similar in size to the diameter of a quarter, and only one third as thick contains approximately 1,760,000 channels.⁹

⁹ Litton, 18mm Microchannel Wafer Tube Image Intensifiers, LIT-223-5M-879 (USA: Electron Tube Division, 1979), p. 6.

Using the MCP, the second generation image intensifier tube is reduced in size by 40 percent of the first generation, and the MCP's ability to localize high current regions, resulting from the influence of bright light sources, reduces the blooming and "wash out" problems encountered in the first generation tube. This results in a much better contrast rendition throughout the system, and the second generation tube requires less voltage. (See Figure 5)



2nd Generation inverter tube — 25mm unit weighs 0.31kgm.

Figure 5

Second Generation Microchannel Plate Image Intensifier (VARO)

The second generation tubes, because of their ability to overcome the deficiencies of distortion, vignetting (due to the reduction of stages), phosphor decay, blooming and wash out, are used in many applications throughout the

military and in education, industry, medicine, and science.¹⁰

¹⁰ Litton, Litton Electro-Optics Department, 5MJA778
(USA: Electron Tube Division), p. 6.

Chapter 3

RESEARCH PROCEDURES

The research procedure for this descriptive study included: a literature search, a request to NVL for information and a list of manufacturers of image intensifiers, a request to TCATA for test/evaluation data on low light level television systems, a telephone interview/request to the recommended manufacturers to obtain information about image intensifier applications, and a study of the brochures, papers, and booklets received.

Subjects

The population for this study was companies that manufacture image intensifiers and low light level television cameras, and the laboratories and agencies that evaluate them. The study dealt with applications other than broadcasting, so some specialized companies were contacted. Some dealt only in government contracts.

The population was recommended by Mr. Dick Franseen of the U.S. Army Night Vision Laboratories. The laboratory has been developing and evaluating image intensification devices for the government for years, and it was felt that a valid list of manufacturers could be obtained from them.

Because the study dealt mostly with non-broadcasting devices, much time was saved by obtaining the list rather than trying to go through the sales representatives of the major broadcast camera manufacturers.

Due to the nature of the study, there was no predetermined number of participants sought, but once a manufacturer was identified it was made part of the study. (See Appendix B) There were a total of 11 manufacturers identified and contacted in this study, and NVL was identified as the only laboratory. One recommended test agency, U.S. Army TRADOC Combined Arms Test Activity (TCATA), was contacted and responded by sending test reports on image intensifier evaluations.

Method of Study

The instrument for this study was a telephone interview. Five areas of application of image intensifier technology were surveyed: military, scientific, industrial, educational, and medical.

Each of the manufacturers and TCATA were contacted by telephone and asked to: (1) Send any pamphlets, articles, sales brochures, test reports, or application information about image intensifiers or image intensification devices applying to the military, scientific, industrial, educational and medical communities; or (2) Over the telephone, address the applications of image intensifiers or image

intensification devices, as they apply to the military, scientific, industrial, educational, and medical communities.

Prior to the actual study, the telephone interviews were discussed with two members of the Graduate College at the University of Wisconsin-Stout.

Interview Procedures

Telephone calls were made to the identified population over a two day period. Each call included an introduction of the background and purpose of the study. (See Appendix A)

Two weeks after the initial telephone call, a follow up call was made to the one manufacturer who had not sent any information.

The telephone calls were made to 11 manufacturers and one Army test agency (TCATA). A total of 10 sent information, an initial return rate of 91.6 percent.

A follow-up call to the one manufacturer who had not responded after two weeks, produced a valuable interview, allowing the researcher to obtain the needed information.

Limitations

Due to the tremendously expanding popularity of these devices, and the ever increasing areas of application, some applications are obviously absent from this study. There are also those applications, classified in nature,

whose existence will not be known for months or years. These applications and the devices used for them should be added to the information in the study as they become unclassified.

Due to the very nature of this study, readers can expand their knowledge by simply adding the new applications and devices to the charts presented in Chapter 4.

Method of Analysis

The information received was compiled and analyzed in three ways. The first was a tabulation of the information received. The second way the information was analyzed was according to type of sensor: image orthicon, vidicon, etc. The third analysis was based on the tube sensitivity of sensors being manufactured. The data are reported on the chart in Chapter 4.

Chapter 4

RESULTS

The basis of this study was a survey taken among manufacturers, the U.S. Army Night Vision Laboratories, and the TRADOC Combined Arms Test Activity (TCATA). The survey was designed to yield information on the application of image intensifiers being used by the military, scientific, industrial, educational, and medical communities. The results of this survey have been compiled and analyzed and may be found in this chapter.

Applications: First Generation Devices

Military Applications

The first generation devices were still rather large, even with the advent of transistorized circuitry. The rifle scope sight was designed for use on any of the army rifles and was attached as shown in Figure 6.

The rifle sight was almost sixteen inches in length, three and a half inches wide, weighed six pounds, and as shown in Figure 6, was almost as large as the rifle it was used with.¹¹

¹¹Headquarters, Department of the Army, Night Vision Sight Individual Served Weapon, TM 11-5855-203-10 (Washington: U.S. Government Printing Office, 1967), pp. 8-9.



Figure 6

First Generation Rifle Scope Sight (NVL)

The crew served weapon scope sight was even larger with a length of twenty-five inches, a width of 7 inches and a weight of 16 pounds. (See Figure 7) The size and weights of both of these sights was due to three items: (1) The optics, (2) The power supply (batteries), and (3) The electronic package required to make it function.¹²

¹²Patrick H. Orell, "Low Light Level Television as an Aid to Army Night Training," Proceedings of the Society of Photo-Optical Instrumentation Engineers, 143 (March, 1978), p. 79.

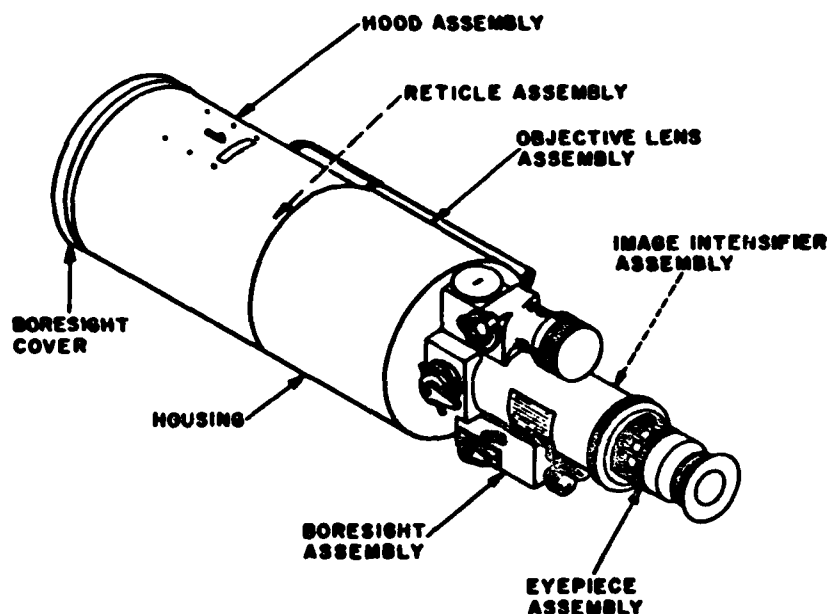


Figure 7

First Generation Crew Served
Weapon Scope Sight (NVL)

Both sights were effective for use in defensive situations where there was moonlight or ambient light being reflected into the area by the stars or from the camps from which they were being used. Because the sights operated in moonlight or with near infra-red illumination, infra-red searchlights were used on occasion to enhance their performance.

There were also devices made for the tanks and armored vehicles that would allow the drivers to be able to see at night, while driving, without using lights. These were powered by the vehicle they were used in, and were very useful in allowing the driver visibility, so he could move

the vehicle at night without having to get out or use a ground guide.

The technology was also used in helicopters in Vietnam for surveillance and target acquisition. One of the systems developed was the Iroquois Night Fighter And Night Tracker system which was called the "INFANT".¹³

(See Figure 8)

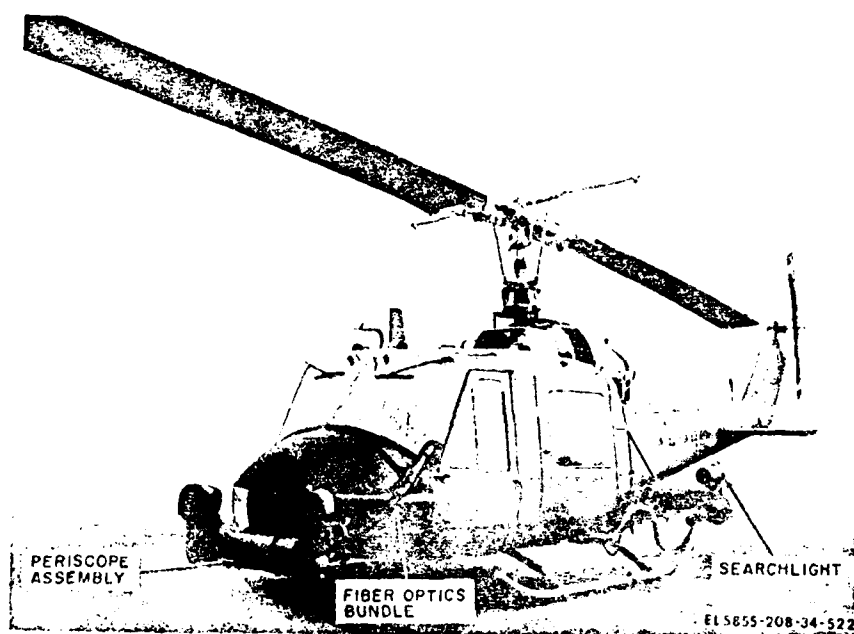


Figure 8

Iroquois Night Fighter and
Night Tracker (U.S. Army)

The INFANT was designed to allow the pilot to fly the helicopter at night by viewing the surrounding area

¹³ Ibid.

through a closed circuit television system. The IIO cameras for the INFANT were mounted on the front of the helicopter and could be controlled from the inside. One camera was strictly for the pilot to use for flying, and a second camera was for observation and shooting the gun system mounted on the sides of the helicopter. There were also two infra-red searchlights which could be used when needed for identification of objects. These were used when there was little moonlight or ambient light available for illumination of the ground. To further improve the helicopter crew's ability, there was a television monitor in the back seat of the helicopter that could be used by an observer for identification of targets or flight assistance. This monitor was connected to the pilot's camera system. The second camera, or scope, was used for the gun system. It incorporated a fiber optic bundle for viewing the images it picked up, and the viewing end was located at the co-pilot's seat. This system gave the co-pilot a clearer image than the TV monitor could and allowed him to freely control the gun system which was coaxially controlled to aim wherever the second camera was looking.¹⁴ This system was effective, but was slightly ahead of its time because the first generation image intensifiers being used for not only

¹⁴ Headquarters, Department of the Army, Army Model UH-1C/M Helicopter, TM 55-1520-220-10/1 (Washington: U.S. Government Printing Office, 1970), pp. 1-2 through 6-6.

the INFANT system, but also the scopes and driver viewers, had certain deficiencies caused by coupling the three stages together. Coupling was the only way to obtain the results required, so these deficiencies were accepted and documented:

1. Distortion and vignetting at each stage.
2. Streaking when a scene containing bright illumination is viewed.
3. Bright light sources within the field of view caused blooming in each stage which can "wash out" the entire scene in severe cases.

These first deficiencies were major drawbacks to the early first generation devices due to the quick light flashes produced by ammunition being fired and explosives. These light flashes would cause the devices to bloom terribly and react with a total "wash-out" of the image being produced. This was usually corrected in a few seconds, but some devices would actually burn out if they received too much light. This problem caused the use of the INFANT to be very selective, and special training was required for the users of the scopes and driving viewers.¹⁵

The Air Force was also using image intensifier technology with a system that would allow an aircraft to fly at a speed of 200 to 300 knots, at an altitude of 100 to 800 feet and identify small targets at ranges up to 2 or 3 miles. The system involved a low light level television

¹⁵VARO Electron Devices, Inc., 25mm MCP Intensifiers, Model 3603 (Garland, Texas), p. 1.

camera, video tracking, laser range finding and ordinance delivery computation. The system is shown in Figure 9, and clearly shows that in order to have the benefit of the technology, spaces for the devices must be made available.¹⁶

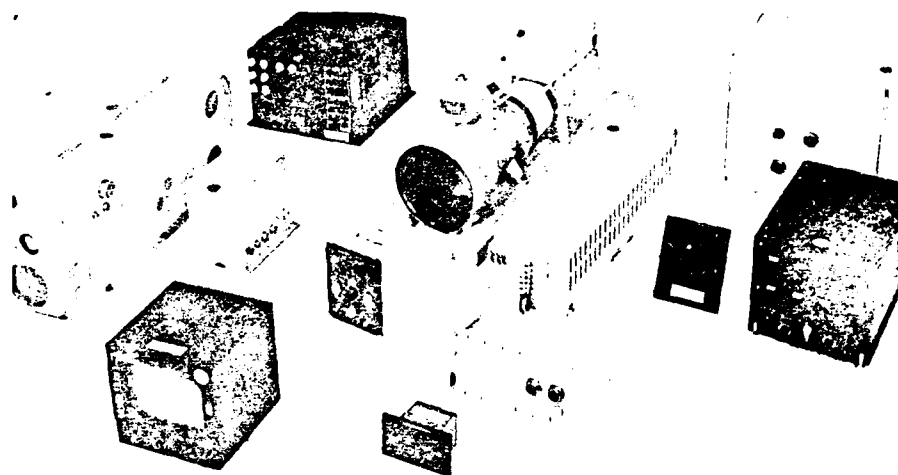


Figure 9

Aircraft Target Detection
System (WESTINGHOUSE)

Education Applications

The first generation single stage and 3 stage electrostatic image intensifiers were used for many applications in the educational environment. By coupling a single stage image intensifier onto a television camera tube, the camera could be used to monitor actions of people, animals, insects and even biological experimentation through a microscope. For any of the applications that require more intensification, and that did not have a bright light source

¹⁶Holtaus and Meacham, op. cit., p. 4.

to cause blooming, a 3 stage image intensifier could be used. An example of what can be done with a TV camera of this type when used with a microscope is shown at Figure 10.

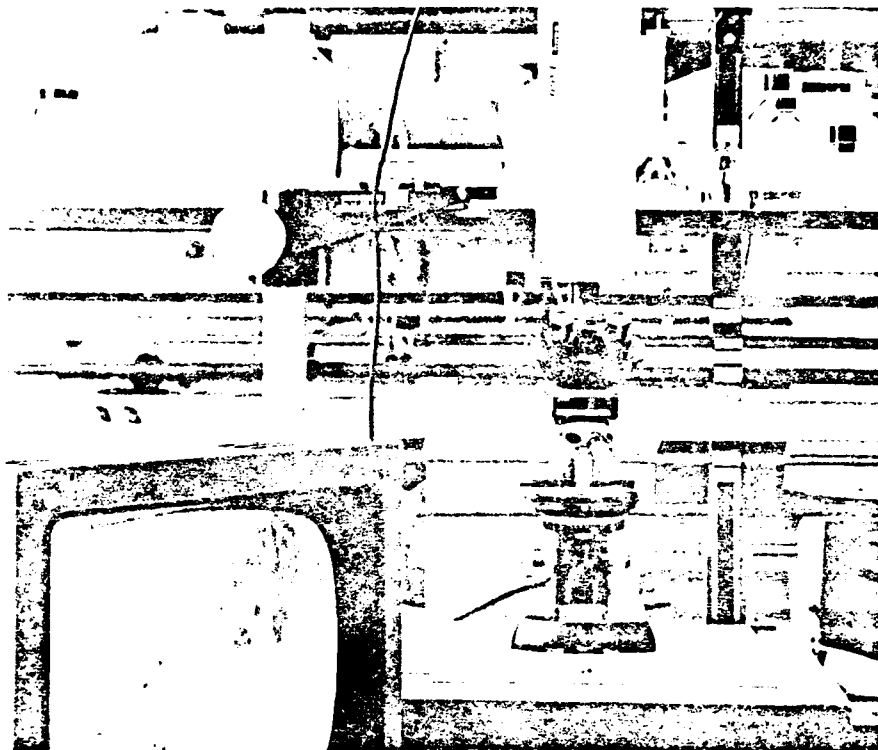


Figure 10

TV Microscopy (COHU)

This application allowed many students to witness the activity taking place under the microscope at the same time and also the capability of video taping the action for further study.¹⁷

¹⁷Westinghouse Electric Corporation, Imaging Devices, SA-110 (Elmira, New York: Electronic Tube Division), p. 4.

In support of entomology, the cameras allowed the researcher/student to observe nocturnal functions of insects without disturbing their natural habitat. Again, the video taping capability was used to share the experience with others.

By using the three stage magnetically focused image tube, photography of exceptional quality could be performed with very little distortion from the image intensifier. This was useful in all the early educational applications.

In normal classroom situations, cameras could be used more extensively without having to use bright lighting which would distract students from instruction. This time frame was the 60's and early 70's when television instruction was just beginning and the new cameras were filling the needs of education by allowing the television audience to be present in the classroom during a lecture.

Industry Applications

Industry had been using television for security and observation in bright illumination for years before the 1965 breakthrough, so conversion to the image intensifier cameras was a simple endeavor. All they did was purchase specific cameras that would fit each lighting condition to be viewed. This was a common practice, and since the technology was new, there were few, if any, cameras that were built without an order placed for them in advance.

By working in this manner the companies producing the cameras were able to classify and evaluate each of their devices in many different lighting and environmental conditions.¹⁸

Areas of early security usage were industrial complexes, parking lots, hallways, subways, banks, department stores, and government facilities. The placement of the cameras and the use of mechanically induced filters would allow the cameras to be remoted and to operate in day and night modes. Environmental housings were developed that were not only efficient, but were also wired with heaters and alarms to make them tamper proof. (See Figure 11)

These cameras were effective in allowing security personnel to watch numerous areas with fewer personnel, not to mention the improved working conditions of a room with TV monitors and camera controls, verses a walk in the dark.

Cameras were also being used by industry to observe assembly procedures on large assembly lines. The cameras could be positioned where a person couldn't, and allow the machine operator to observe functions from a safe distance away.¹⁹

¹⁸James A. Prell, Basic Considerations for Assembling a Closed-Circuit Television System, Nuclear Regulatory System, NUREG-0178 (Washington: National Technical Information Service, 1977), p. 3.

¹⁹General Electric Corporation, 4TE-37 Nitegard (USA: 1979), p. 1.

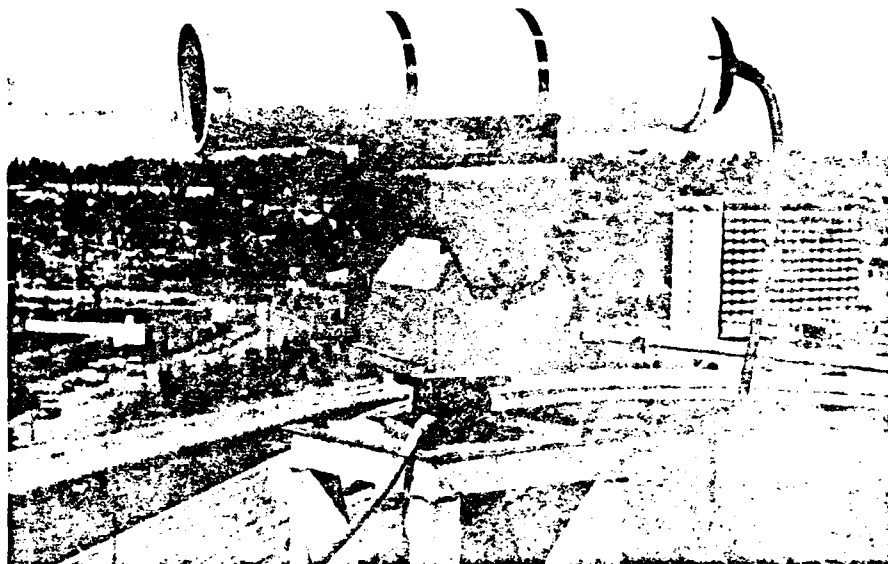


Figure 11

Environmentally Housed Security
Camera (COHU)

Science Applications

Television pictures that were transmitted from the moon's surface in black and white for the Apollo 11 mission in 1969 were made possible by a low light level television (LLTV) camera. The camera (see Figure 12) was small, weighed only 7 pounds, and incorporated a one-inch electrostatically focused intensifier sec vidicon (ISEC) to be able to view in areas of low illumination.

A second camera was developed that would produce color video information under extreme lighting and scene content variations, and was used on Apollo 10 and 11 missions.

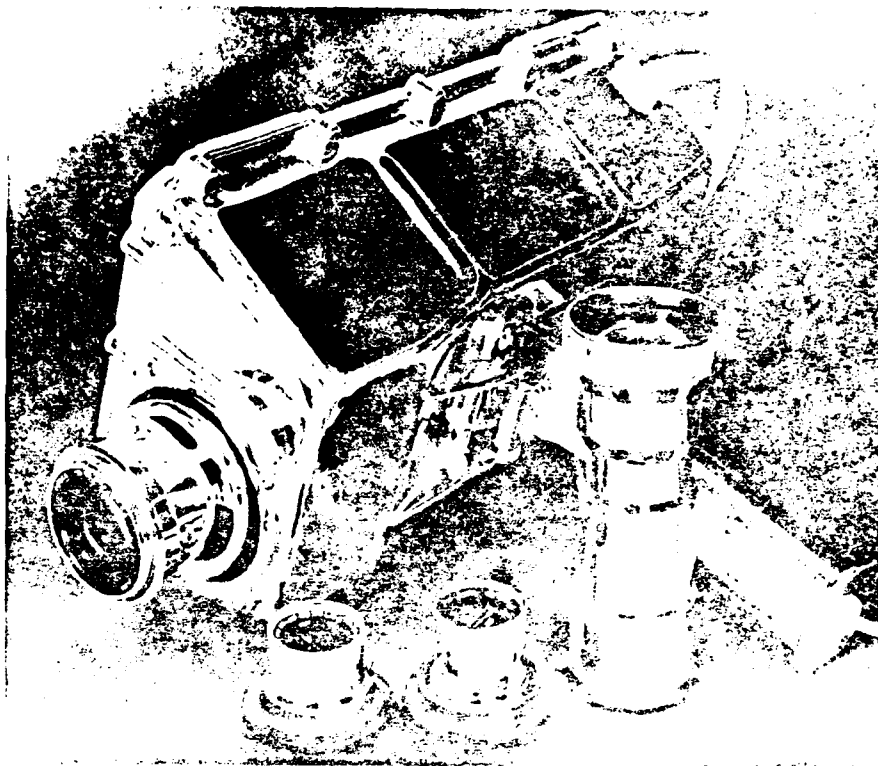


Figure 12

Apollo Lunar Camera
(WESTINGHOUSE)

(See Figure 13) The exact make-up of this camera was not made available, but its existence at that early stage in development demonstrated that image intensifier technology was progressing at a tremendous rate.²⁰

²⁰Westinghouse, loc. cit., p. 12.

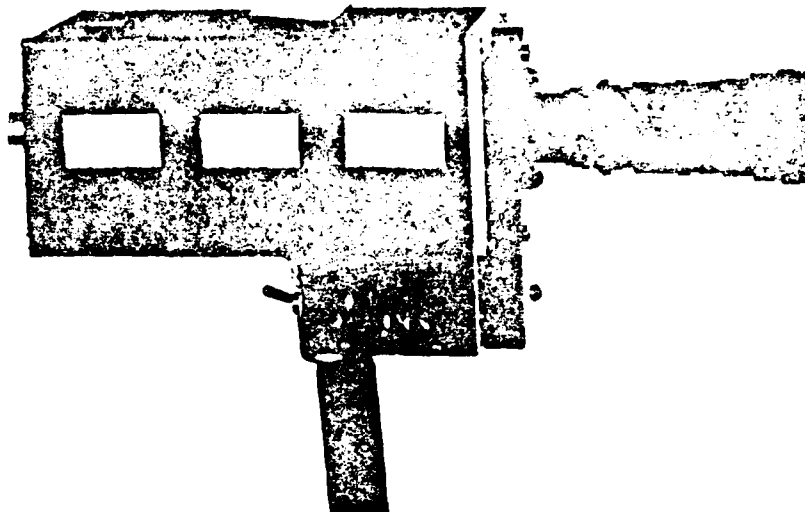


Figure 13

Apollo Color Camera
(WESTINGHOUSE)

Applications: Second Generation Devices

Military Applications

The rifle scope sight requirements were, and are still, the same as with the first generation devices, but the size has dropped considerably. Also the newer scope sights can be used in daylight or night conditions with the use of neutral density filters, which can be attached to the front of the sight. The sight is larger in diameter, but much shorter and due to the new 2nd generation tube and micro electronic circuitry the power required is less with longer operation time. The new rifle sight weighs less

than 3 pounds and is approximately two-thirds as long as the old sight.²¹ (See Figure 14)



Figure 14

Second Generation Rifle
Sight Scope (NVL)

The crew served weapons sight has also been reduced in size and incorporates the same filters and micro electronic circuitry. It now is only 12 inches long and weighs

²¹Army, TM 11-5855-203-10, op. cit., p. 9.

only 8.1 pounds.²² (See Figure 15)

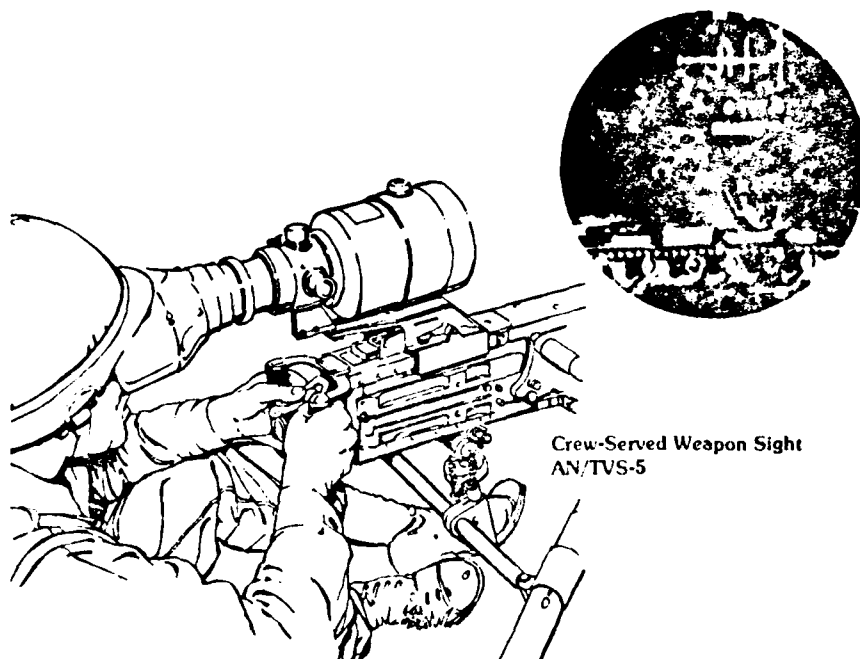


Figure 15

Second Generation Crew Served
Weapon Sight (NVL)

The driver viewer for tanks and tracked vehicles has also been upgraded to the 2nd generation and has greatly enhanced the drivers capability to move the vehicle at night, while the vehicle is firing, and also aids the driver in being able to detect enemy usage of near infra-red driving and weapons control systems.²³ (See Figure 16)

²²Army, TM 11-5855-202-13, op. cit., pp. 1-5.

²³U.S. Army Electronics Research and Development Command and Night Vision and Electro-Optics Laboratory, Night Vision, (Ft. Belvoir, Va.: 1979), p. 12.

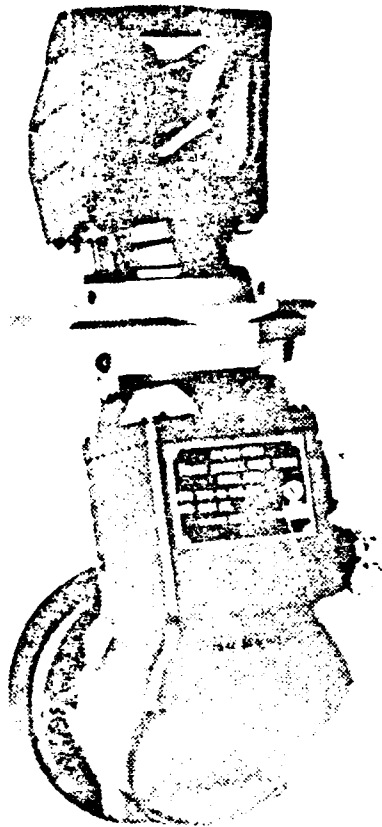


Figure 16
Second Generation Driver
Viewer (NVL)

A new system has emerged with the second generation tube, called night vision goggles. These goggles are a completely self contained night vision system that provides the user viewing capability under moonlight and/or starlight conditions. (See Figure 17)

The goggles use two second generation wafer type image intensifier tube assemblies, each having an 18mm

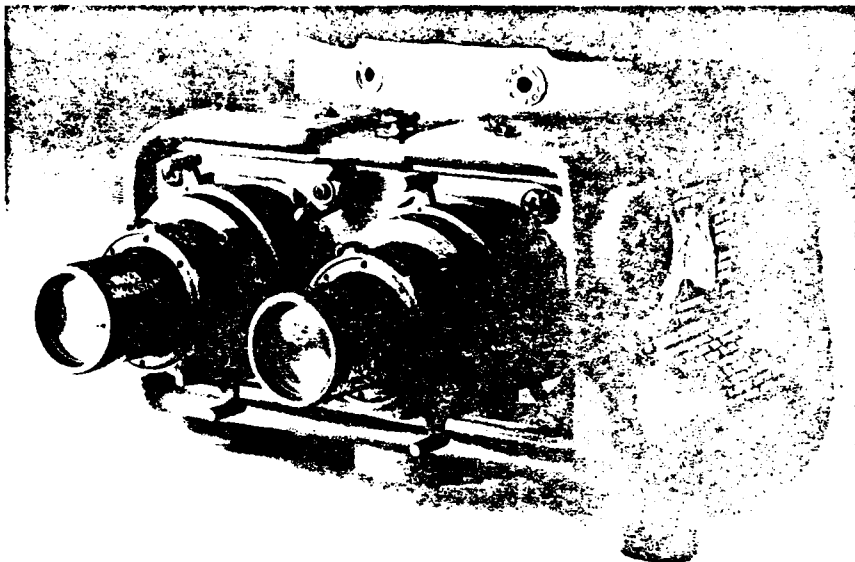


Figure 17

Night Vision Goggles (LITTON)

image format (the sights use a 22mm format). Each side of the goggle has its own power supply (battery) to provide operational reliability. They are lightweight, passive, rugged, focus from 10 inches to infinity, have a 40 degrees field of view, automatic brightness control, and have a protection circuit built in them for bright light source protection.

The military uses them for: Vehicle driving, (see Figure 18) Helicopter flying, Patrols, Weapon aiming, (see Figure 19) Paramedic night work, and Security.²⁴

²⁴ Litton, Look to Litton for Night Vision Goggles, LIT-196-5M-679 (USA: Electron Tube Division, 1979), p. 1.



Figure 18

Night Vision Goggles, Driver
Application (LITTON)

Figure 19 shows the goggles being used with an infra-red aiming light which is attached to the rifle, just above the soldier's left hand. The image shown in the circle above the soldier, is the view that the soldier has of a person. The white dot on the person's chest is the infra-red light. The light and the rifle are calibrated (sighted) so that the rifle, when fired, will strike where the light is shining.²⁵ This system is impressive, however, each

²⁵U.S. Army Electronics Research and Development Command and Night Vision and Electro-Optics Laboratory, op. cit., p. 11.

time a soldier uses it he will be giving away his position to any other enemy soldiers who have metasopes or infra-red viewers. These goggles have been used successfully for law enforcement using the light, however, and other uses will be covered under medical, scientific and industrial applications.

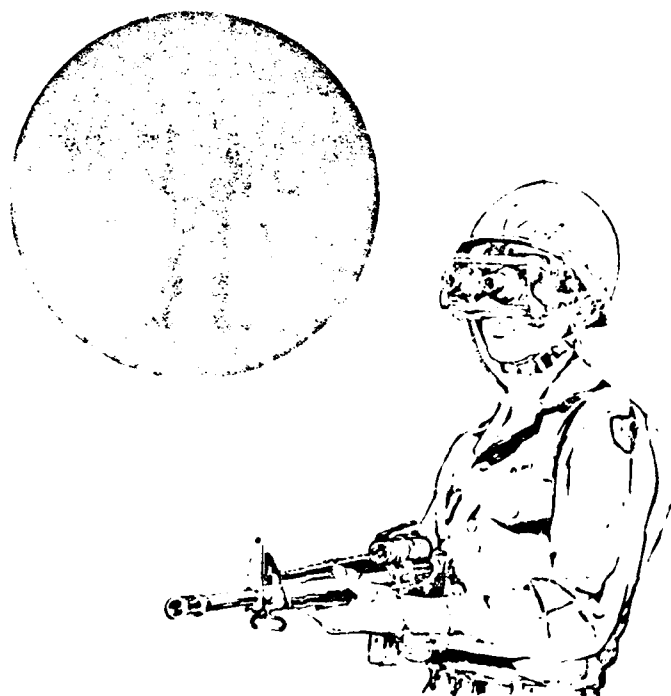


Figure 19

Night Vision Goggles, Weapon
Aiming Application (NVL)

To further assist the reader in being able to assess the capability of the second generation devices being discussed, Figure 20 shows a chart that explains the numerical ratings applied to image intensification devices.

These numerical ratings are actually nothing more than expressions of light level.

LIGHT LEVEL CHART

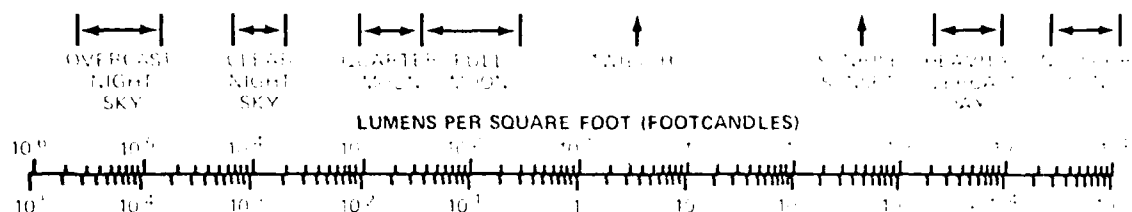


Figure 20

Light Level Chart (COHU)

Using the chart, one can easily see that 10-1 lumens per square foot (footcandles) is equal to what the eye sees at the darker edge of twilight. Twilight is when the stars are visible, but there is still a small amount of skylight from the sun which has already set. As it gets darker, the number 10-2 footcandles might be used to denote a full moon, or 10-4 would be used to denote a clear night sky. As one looks across the chart it is clearly shown what numerical footcandle applies to which condition.²⁶

The capability of the sights used by the military vary, but the following are the capabilities of the four discussed. The rifle sight (AN/pvs-4) is unrated, with a statement for range which says "Dependent on surrounding

²⁶ COHU, Inc., High Sensitivity Television Cameras in Low Light Applications (San Diego: Electronics Division, 1976), p. 11.

light level."²⁷ The crew served sight (AN/pvs-5) is rated at "100-1200 meters for vehicle targets in starlight (10^{-4}) and moonlight ($10^{-2}/10^{-3}$)."²⁸ The night vision goggles (AN/pvs-5) are rated to be able to see a six foot object at up to 492 Feet in a quarter moon (10^{-3}).²⁹ The driver viewer (AN/vvs-2) information was not available.

The sights discussed thus far are also used by the other services for the same basic applications. The Navy, however, also uses LLLTV cameras for assistance in viewing flightdecks on aircraft carriers and being able to see under water. One project where extensive use is made of LLLTV is in the Navy's Deep Submergence Rescue Vehicle (DSRV). This vehicle (shown in Figure 21) is used to transfer men from a disabled submarine, acting as a shuttle between the stricken vessel and another submarine hovering overhead. The cameras are mounted on the vehicle so that the operator can use them in locating and linking up with the downed submarine.³⁰

The Air Force and Navy have made extensive use of image intensifiers for target acquisition and munition delivery on high performance aircraft. The information

²⁷Army, TM 11-5855-203-10, loc. cit.

²⁸Army, TM 11-5855-214-10, op. cit., p. 1-4.

²⁹Litton, LIT-196-5M-679, loc. cit.

³⁰COHU Electronics, Inc., Underwater TV, 8-100 (San Diego: 1969), p. 7.



Figure 21

Deep Submergence Rescue Vehicle (COHU)

available described systems that utilize laser designators to mark the target and range to it, after a LLLTV camera/tracker system enabled the pilot to acquire the target. Once the munition was released from the air craft, the camera system and laser designator would allow the pilot to continue to mark the target and guide the munition to its destination. These systems, being produced by a number of companies, are designed to integrate system performance requirements with size, weight and shape constraints while continuing to maintain proper interface with the aircraft it is mounted on. They are becoming rapidly more popular,

as the image intensifiers being developed for them are becoming smaller and better. These systems are usually hung underneath the aircraft and are easily detached for replacement or maintenance. (See Figure 22)



Figure 22

Laser Designator (MARTIN MARIETTA AEROSPACE)

The information provided stated that successful use of image intensifier technology had been made by all the services, but that almost all projects were classified.³¹ (Note! Applications of image intensifiers in support of military training will be covered in education applications.)

Education Applications

The 2nd generation image intensifiers are used for many applications in education. The applications of the first generation image intensifiers are continuing, with second generation devices replacing them where needed.

³¹Ronald E. Johnson, "Optical Engineering of First and Second Generation Automatic Tracking/Laser Designator Pods," Proceedings of Photo-Optical Instrumentation Engineers, 143 (March, 1978), p. 70.

The microscope application has been enlarged to cover all kinds of microscopes. When light sources can disturb the objects under observation, the LLLTV cameras have opened up the capability of being able to view under infra-red light at very low illumination levels. The images picked up can be video taped for further evaluation or monitored directly in another room.

A combination education/medical application is for LLLTV cameras to be used to view low illumination x-ray devices, called fluoroscopic generators. By using the camera to read the image being produced by the x-ray machine, the actual radiation source can be made smaller and the radiation dose will also be smaller. This allows study of body tissue to be safer, not to mention the reduced exposure time to operators. Again, the use of LLLTV cameras allows video tapes to be made for further study.³² (See Figure 23)

The night vision goggles and the LLLTV cameras are used in education for viewing nocturnal entomology and in nocturnal wildlife surveillance. The goggles are especially helpful for the observer to be able to move more quietly through forrested areas and view animals that would have been frightened away by an observer trying to set up the older first generation devices, or the presence of large

³²COHU, Inc., Closed Circuit Television, Short Form Catalog, 6-543 (San Diego: Electronics Division, 1976), p. 10.

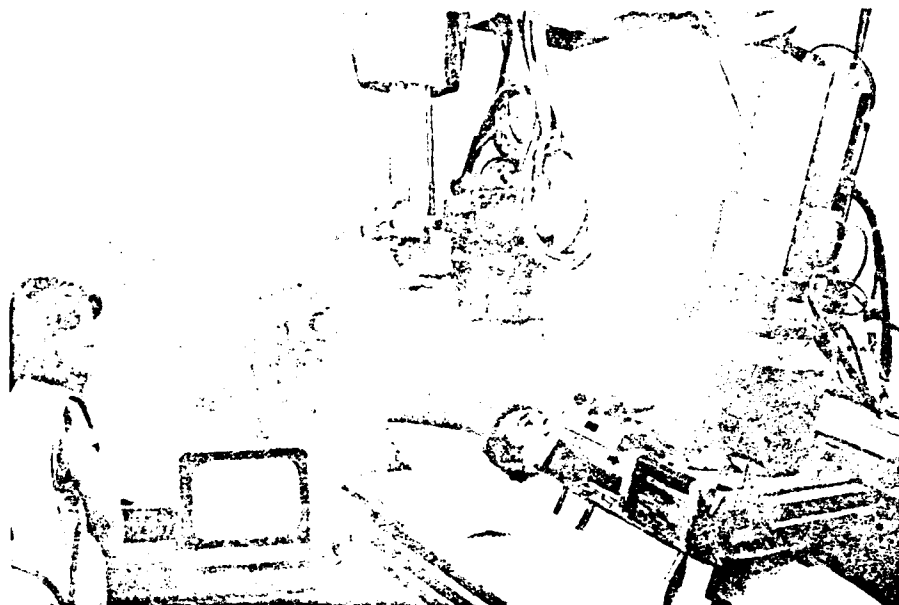


Figure 23

Fluoroscope With Interfaced
LLTV Camera (COHU)

viewing stands or vehicles.³³

A different style of nightvision goggle is the "Cyclops" night vision goggles. They are cheaper in cost because they use only one image intensifier and deflect the one image into two eye pieces. They are used for some motion applications, for development of super sensitive films under IR illumination and for viewing stationery laboratory experiments.³⁴ (See Figure 24)

³³Litton, LIT-196-5M-679, loc. cit.

³⁴VARO Electron Devices, Inc., 1979 Personal Planner (Garland, Texas: 1979), p. 9.



Figure 24

"Cyclops" Night Vision Goggles (VARO)

In the area of educational research, an advanced electro-optical system using an image intensified tube was used to measure single and average blade tip clearances between a rotor and its gas path seal, in an operating gas turbine jet engine. By using the electro-optical system, the researcher could access the engine without disturbing its normal operation.³⁵

³⁵M. J. Ford et al, Advanced Optical Blade Tip Clearance Measurement System, NASA CR-159402 (Washington: 1978), abstract.

The military services, being the original users of image intensifier devices, also use them for training. Other than just using them as they train for combat, they use other devices to support the education of their personnel.

The Navy uses LLLTV cameras to view and video tape helicopter and fixed winged aircraft as they take off and land on ships and aircraft carriers. Because of the total blackout conditions (all lights off) that the ship must operate under during combat and combat simulated training, LLLTV is an excellent means of controlling and evaluating the operations. By having constant view of helicopters attempting to land on the decks of ships, the ships crew can alert the pilot if there is any danger of striking part of the ship or personnel. The pilot has the aid of night vision goggles, but even in the daytime the ship's crew observes and talks to the pilot over the radio about safety and wind situations. This can now be done on a 24 hour basis and the pilots can critique themselves by viewing video tapes and listening to the radio transmissions that are simultaneously recorded by the TV system. The same activity takes place on aircraft carriers, where the control of aircraft on deck, taking off or landing is critical.³⁶

³⁶ Presentation by COHU representative in an address ("Low Light Level Television Cameras") at Headquarters, TRADOC Combined Arms Test Activity, Ft. Hood, Texas, April 1977.

The Army is in the process of developing a small, lightweight, manportable, LLLTV system for the documentation, control, and evaluation of night training. It has conducted feasibility tests and found that using the systems does offer field evaluators an excellent means for controlling and evaluating soldiers during maneuvers and during tank gunnery qualification. The video tapes produced are also excellent for critiquing the soldiers.

The camera system (see Figure 25) evaluated by the Army was made up of a LLLTV camera that used an image intensifier coupled to a new tube called a "silicon intensified target" vidicon. This is basically the same configuration as the other intensified tubes discussed, except that a component called a silicon intensifier target (SIT) is now placed between the image intensifier and the faceplate of the vidicon tube. The three are coupled together. The SIT component accelerates the image produced by the image intensifier before it is scanned by the traditional vidicon tube components. This (ISIT) tube gives the camera an all electronic 10,000:1 dynamic light range. This allows the camera to produce excellent pictures at 10^{-4} (clear starlight sky) conditions; as well as being able to continue functioning during bright light flashes, or flare illumination produced by the soldiers during night training.

This camera is connected to a portable video recorder which is carried by the user, and the power to run

both the camera and the video tape recorder is furnished by a battery belt.



Figure 25

Army LLLTV System For Training
Evaluation (U.S. ARMY)

The toughest performance and durability test of this camera system took place when the army evaluated it as a device to score night tank gunnery. During this training it is difficult for evaluators to see the targets or be able to accurately score them at ranges of 1000 to 3000 meters, especially if evaluators are partially blinded by the flash given off when the tank is fired. To be as far away from the flash as possible, evaluators would usually score from

three separate vantage points and then call in their sensings to a central scoring station using a radio. The system works, but there is no way to check your sensing or to show the tank crew their hit or, most important, their miss. To assist in correcting the problem, the LLLTV camera system was used. It was found that by putting a 500 mm lens on the camera and setting it at F 1.8, a very clear picture of all targets could be made during firing. This enables the evaluators, from only one position, to accurately score each round fired. If there was any doubt about a round's impact, they could replay the tape and view it as many times as they needed. The tapes were also valuable as critique devices to show the tank crew how they performed. Another "plus" for the camera is its ability to sense infra-red light. As was stated earlier in this paper, infra-red light is used selectively by soldiers to illuminate targets. The IR capability of the camera makes its video pictures look as if they were taken in normal daylight whenever infra-red light is used to illuminate a target. Again, the video tapes can be used by evaluators to critique the proper use of infra-red illumination in not only tank gunnery but also in other night training.³⁷

³⁷James H. Meacham, Television for Night Training Scenarios (Baltimore: 1979), pp. 1-5.

Industry Applications

Industry has welcomed the second generation tube and has put it to many new and varied applications. Because of this, the companies that manufacture cameras have come up with many different models for the many applications.

The first generation cameras used for observing assembly procedures on large assembly lines are being replaced with the second generation devices because they are smaller, use less power and require less light. They are being used in even more areas to observe functions of machinery that could not have been viewed with the first generation tubes. The second generation tubes are more stable and new television tubes are being developed to use with them. A tube called an "isocon" has been developed for the specific purpose of observation of detail in moving objects. The cameras built with these tubes can produce usable pictures in the range of 10^{-4} to 10^{-3} footlamberts of illumination. An "intensified" isocon can produce usable pictures in the range of 10^{-4} to $10^{-4.38}$.

Cameras are also being used for observation of dangerous or hazardous functions in industry. An example is the inspection of nuclear reactors, where there are toxic, flammable, or corrosive chemical vapors and liquids present as well as radiation. Small cameras with light

³⁸ COHU, Inc., 6-543, op. cit., p. 6.

sources attached can be lowered into areas as small as 3 inches in diameter to view the condition or operation of parts.³⁹ (See Figure 26)

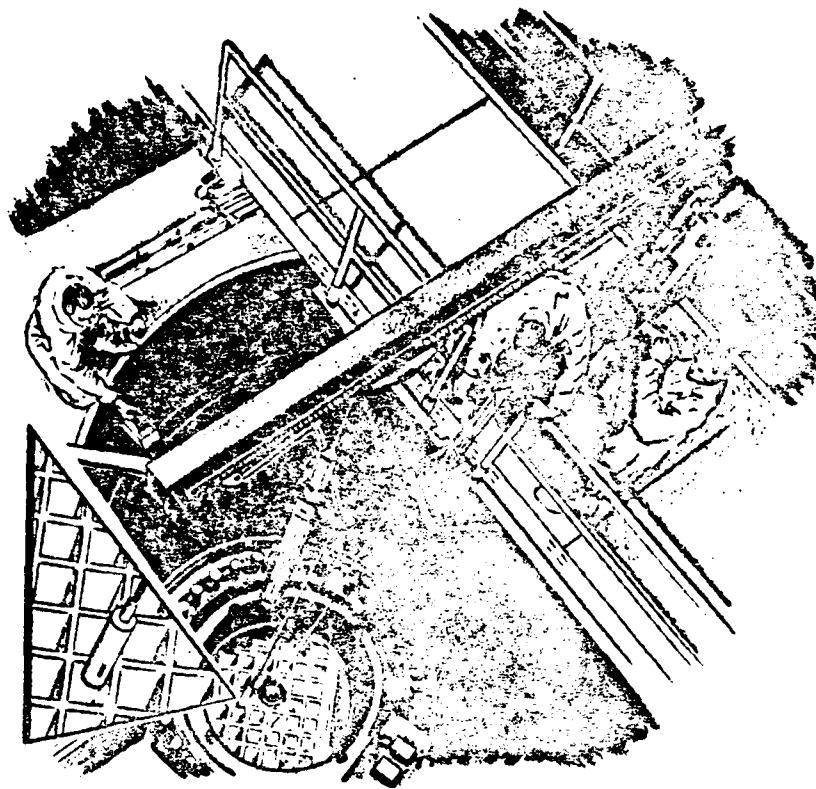


Figure 26

Nuclear Reactor Inspection (COHU)

Cameras are being used by the mining industry to be able to view into areas that cannot be reached by men. They lower a camera down a drilled 3 inch wide shaft and observe the open pockets to assist the mining engineers in being

³⁹COHU, Inc., 2000 Series System Planning Diagram (San Diego: 1976), p. 2.

able to speculate ore content of the ground. The small cameras have also been a great asset to mine rescue efforts. They can be lowered down shafts to trapped miners and allow not only information about the condition of the miners to be known, but also assist medical personnel in being able to talk with miners. By having this contact with them, the medical personnel can actually talk them through first aid or even more delicate medical applications and save lives.

The same type of camera used in the nuclear reactors is being used for the quality inspection of the welding done on the inside of pipe sections and the welded seams of ships. (See Figure 27) The cameras have proven to be



Figure 27

Welding Inspection (EDO WESTERN)

very valuable in checking the welded seams, and are used in conjunction with the normal x-ray methods to insure that the welds will stand the pressures for which they are designed.⁴⁰

Cameras are also used by the oil industry in the process of locating exact re-entry of oil drilling equipment into the same hole it came out of on the bottom of the sea. When equipment is removed from the sea bottom for maintenance, it is like "threading a needle" to get it back in again, especially from a ship that is hundreds of feet above the hole. By lowering a small camera and light source down the pipe, the operators can see where to place the drill bit. To aide the operation, sonar acoustic devices are used with it to seek out a specially designed guide base and drilling template which has some target sonar emmitors built into it. This system saves the oil industry much time and prevents costly damage to drilling equipment. (See Figure 28) On land, the oil companies also use cameras that are lowered down the hole, for the inspection of casing pipe to prevent costly down time and to avert damage to equipment.⁴¹ (See Figure 29)

⁴⁰Statement by James H. Meacham, electronic engineer, Electro-Optical Systems Development, Systems Development Division, Westinghouse Electronic Corporation, in a telephone interview, January 21, 1980.

⁴¹Edo Western, Deep Water Re-Entry Systems (Salt Lake City: 1979), pp. 9-12.

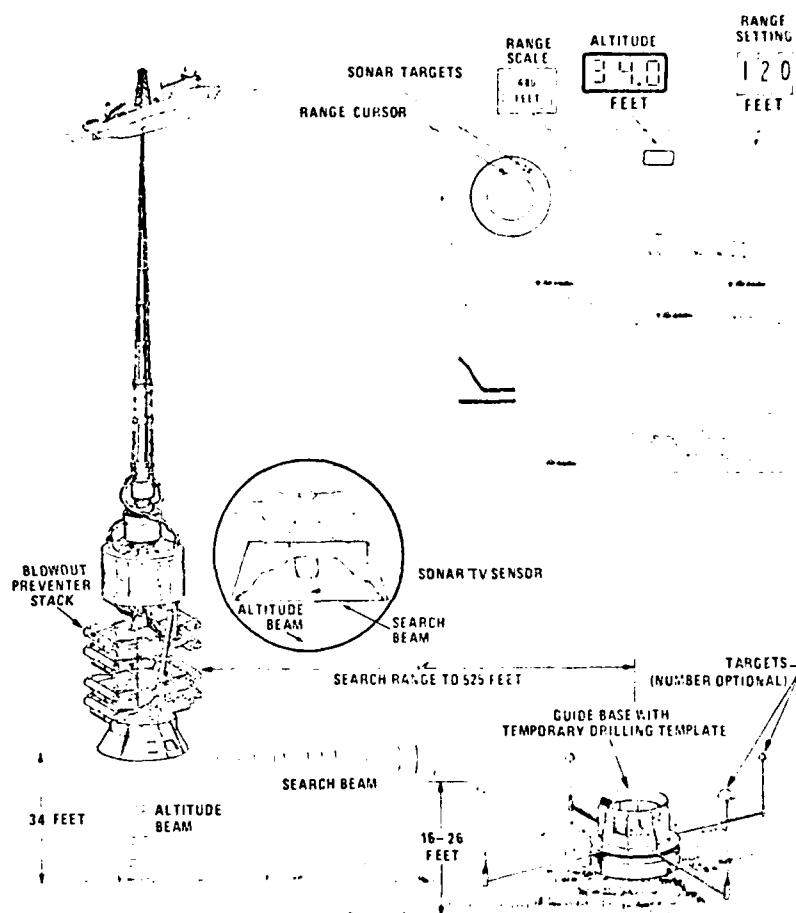


Figure 28

Oil Well Re-Entry System (EDO-WESTERN)

Security applications have expanded to the use of the night vision goggles and to smaller cameras. The companies manufacturing the cameras have developed complete systems that include environmental camera housings, spotlight systems, and two way inter-communications systems that allow the security guards to talk to persons the cameras are viewing. Color cameras have even been developed that aid

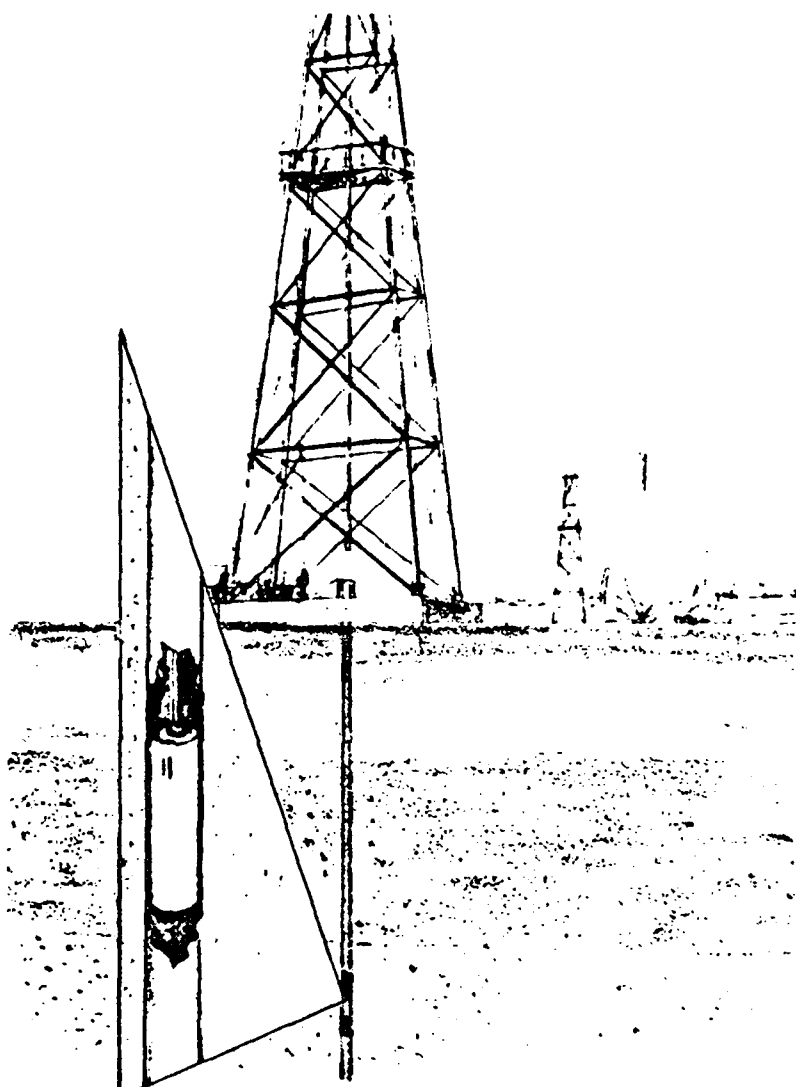


Figure 29

Oil Drilling Casing Inspection (COHU)

in the identification of objects. These cameras will produce pictures at 10^{-1} (twilight) and do require some light assistance in darker situations, but have been very useful in identification of automobile or clothing colors. The image isocon equipped camera has been used for the

enhancement of x-ray displays in airport security applications, and allows the security guard to take a video picture of the inside of luggage and hand carried items, allowing viewing of the video tape for longer periods without subjecting them to excess radiation.⁴²

The night vision goggles are used for surveillance applications where cameras cannot be installed, and have proven very valuable in search/pursuit, and drug control.⁴³

There is also a small night viewer available that can be used for viewing or photography. This device comes in a number of models and can be used with various cameras or by itself as a scope. It has been used by police and security personnel, and has been made available for sale in department stores. Many have been sold to boat owners for the purpose of navigating in ports or along coastlines.⁴⁴
(See Figure 30)

The Coast Guard uses night vision goggles, shipboard and helicopter mounted cameras in support of their search and rescue missions. They have proven to be invaluable at night in spotting persons or boats by attaching telephoto optics to the cameras and using IR or visible light. This combination is much better than the human eye and binoculars.

⁴²COHU, Inc., 6-543, op. cit., p. 6.

⁴³Litton, LIT-196-5M-679, loc. cit.

⁴⁴VARO, op. cit., p. 25.

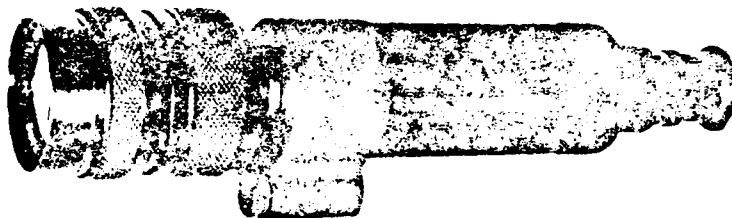


Figure 30

Noctron IV Night Viewer (VARO)

Without lights, the items mentioned are also excellent for surveillance, search and pursuit.⁴⁵

Because of the image intensifier being able to sense IR light given off by a fire before the human eye could see visible light, the forestry service has used the night vision goggles and scopes for surveillance of forests and in fire fighting efforts. Using the goggles they can see the true outer edge of the fire, where the naked eye might not.⁴⁶

Science and Medical Applications

The scientific applications of image intensifiers have grown along with the capability of the devices being made with second generation technology. The scientific

⁴⁵Statement by James Meacham, loc. cit.

⁴⁶Ibid.

community has applied the cameras in the sea, on earth and into deep space. The first generation applications, have been upgraded to second generation devices where needed, and the following new applications are of interest.

Underwater photography has been popular and useful for many years. Now underwater television is available and by using second generation devices, the light requirements are cut to a minimum. This allows nocturnal studies to be conducted more realistically and even in color where required. With the newer camera housings and lightweight cable, a diver can carry the camera down to the depths required and be told what to do by a scientist over an intercommunications system. (See Figure 31 and 32) This allows the scientist to video tape actions needed, and then direct the diver to the surface. The video tapes are then studied by the scientists who may "instant replay" the action as many times as they need. The key to this method is that the diver is not in the water as long, and if there is a danger involved, the camera can be mounted on the bottom of the ship or on a pedestal on the bottom. These remotely mounted cameras can be controlled from the ship and can pan, tilt, zoom, adjust F-stop, and can be designed to turn on light sources if required.⁴⁷

⁴⁷COHU, Inc., 6-543, op. cit., p. 2.



Figure 31

Underwater TV System (EDO WESTERN)



Figure 32

Underwater TV Image (EDO WESTERN)

Specially built "explosion proof" cameras are used by scientists to observe rocket engine testing and rocket launching. These cameras are especially useful in the shadowed areas or where illumination variance causes normal cameras to bloom. When equipped with remotely activated zoom lens systems the cameras afford scientists a simultaneous close view of functions which they were not able to obtain before.⁴⁸ (See Figure 33)

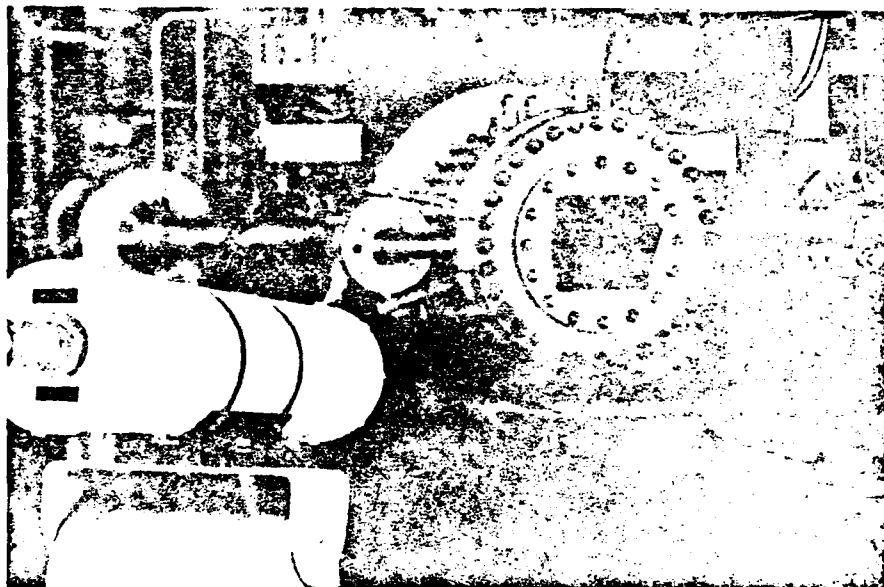


Figure 33

Rocket Engine Testing (COHU)

The space program has used cameras for monitoring functions inside space craft and also for observing views on the outside of various types of rockets. One documented

⁴⁸Ibid.

application was the "Black Brant" rocket that carried a small television camera that could be operated via radio from earth. The camera enabled scientists to point instruments more finely by manually commanding the firing of the rocket's control thrusters. This application in 1977, yielded "the first observation ever made of a quazar in the ultraviolet region of the spectrum." The camera used was equipped with a SIT television tube.⁴⁹ Special cameras have been used for almost all space flights and for various applications. Their specific use for documentation is classified. However, most of the black and white and color TV images released to news agencies and television are made possible because of image intensifiers.

Observatory applications are becoming common since the first generation devices were introduced, and astronomers can now view stars never before seen by the naked eye. Video tape and remote monitors allow further study of findings. The sensitivity of these cameras has allowed astronomers to video tape stars clearly, without encountering distortion from the earth's rotation. Distortion and smearing was encountered using timed photographic techniques. By using specially made magnetically focused intensifiers to brighten the image, clear photos can now be made using faster camera shutter speeds. Satellite tracking is also

⁴⁹ Edo Western, "The Flying Fish," Edo Western Corporation News, Fall, 1977, p. 10.

easier to accomplish using either intensifier method.⁵⁰

Scientists and doctors in the medical field are using second generation technology to make their work safer and to expand their capability. One of the most publicized applications is that of the night vision goggles to assist persons who are afflicted with Retinitis Pigmentosa, commonly called night blindness. People who suffer from this are virtually blind in absence of normal room light. This affects persons differently of course, but by wearing the goggles persons can now function normally when in low illumination areas. Because of the importance of this single application, the goggles are made available, at a reduced price, to persons diagnosed as night blind.⁵¹

The goggles are also used by eye surgeons to perform low light ophthalmological surgery. By using the goggles, the light intensity can be kept to a minimum which causes the pupil of the eye to remain open as if dialated. Cameras are also used to assist the surgeon in magnification. This condition allows the surgeon better access to the inner eye, without the use of drugs.⁵²

Scientists are experimenting with x-ray devices which incorporate image intensifiers and cameras. By using

⁵⁰Westinghouse, op. cit., p. 11.

⁵¹Litton, LIT-196-5M-679, loc. cit.

⁵²Ibid.

a source that emits radiation that can be sensed by specially made intensifiers, it is possible to scan the area faster with less radiation and then study the video tape. This technique has also been used with radioactive dye that can be injected into the body and then its flow can be traced by the camera. The added bonus to this method is that video tape is cheaper than x-ray film and can be easily transmitted to distant places via telephone circuits to obtain expert advice from other doctors about cases.

Using a camera to sense images produced at the end of a fiber optic tube allows a surgeon to make a smaller incision and use electronic processing to magnify the image for examination. The fiber optic tubes can be made very small and will conduct enough light to activate the intensifier.

Because of the sensitivity of the second generation device and the advent of specialized optics, scientists are actually studying the fluid flow in cells. Through a technique called "slit-imaging", scientists can now begin to understand discrepancies in cell measurements due to cell orientation and dynamics in cell flow. This application is a major breakthrough for scientists and requires the use of a SIT vidicon tube and specially designed "slit-scan flow" optical systems. The systems are still being

evaluated but show great promise.⁵³

Scientists are also using cameras as instrumentation for experiments. Where electronic controls were used before, cameras are now used to back them up. There are various methods of application, but the most common is to use the cameras for documentation of activities. Time and date information can be integrated into the image picture being recorded on video tape. By viewing the tape the researcher has not only the visual image of the activity but also the time, date, blood pressure, temperature or any other variable he might wish to incorporate into the picture. This technique is not new, however its application has become more widespread with the introduction of the less obtrusive image intensification devices.⁵⁴

New Developments

All the devices discussed thus far have been made using television tubes for the generation of a television picture signal. These tubes are rather bulky when compared to the low power micro-electronic circuitry that operates them. This micro-electronic technology has been applied to the television tube and has caused development of a new

⁵³David B. Kay, James L. Cambier, and Leon L. Wheels, Jr., "Imaging in Flow," The Journal of Histochemistry and Cytochemistry (USA: 1979), pp. 330-331.

⁵⁴Patrick H. Orell, "Scoring Tank Gunnery by Instant Replay," Armor Magazine (May-June, 1977), pp. 23-24.

form of imaging device called the charge-coupled device (CCD). The device was discovered in 1969 at Bell Laboratories and after 11 years of development is being used to replace the television tube in areas where small cameras are required. (See Figure 34)

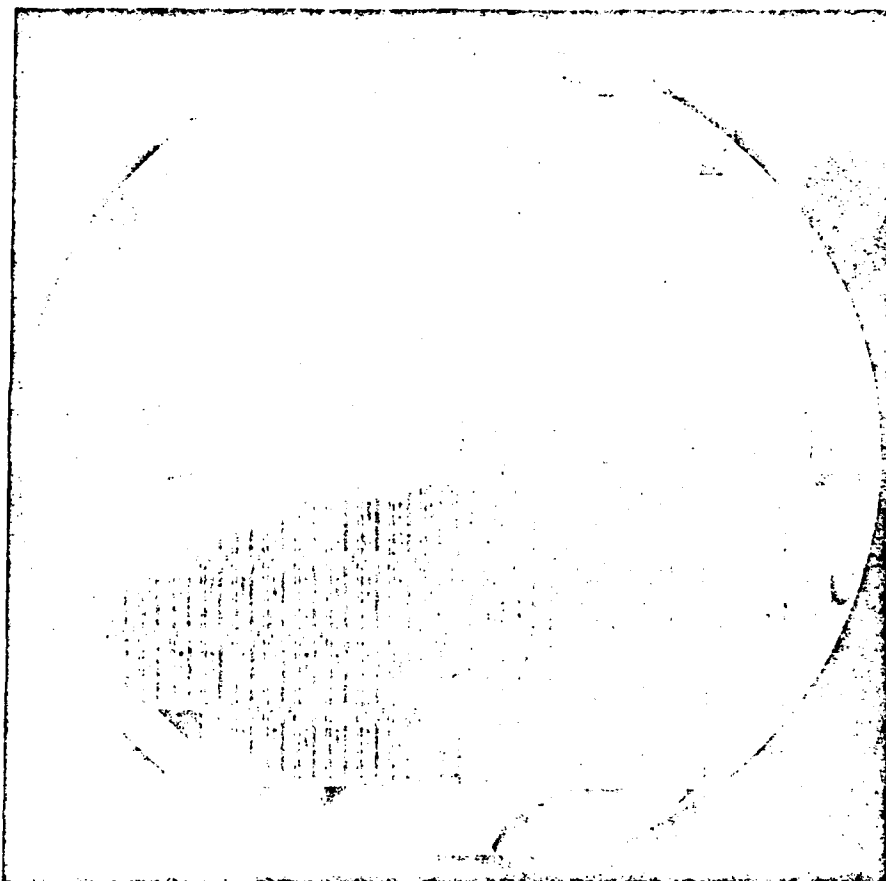


Figure 34

Charge Coupled Device (FAIRCHILD)

The CCD functions like a television camera tube in that it receives incoming light and converts it into an

electronic signal. It does it with computer circuitry technology, making use of microscopic patterns of electrical charge elements (electrodes). These electrodes have various charges dependent upon the amount of light focused on each one. Basically, each electrode sends an electronic signal, which is processed into an image by the video processing circuitry in the camera. Some CCD arrays have over 1700 electrodes which can allow a user to obtain high resolution pictures. The cameras can be made to work with video recorders, computers and telephone signal processing devices for communication applications.

The CCD has opened up the image intensifier technology field again by allowing for even smaller devices that can use lower power, have greater sensitivity in specific applications, and longer life.

The military is making use of this technology in its pilot training for tactical fighter aircraft. Before, gunsight image recording of combat and training operations was accomplished using 16 mm film cameras. Using CCD imaging cameras to provide gunsight recordings on video tape, the real-world image data can be viewed immediately after landing, without having to wait the previously required hours for film developing. Video tape also can be used to record longer than the film system can (30 minutes versus 10 minutes).

These systems are called Cockpit Television Sensors (CTVS) and are being purchased by the services for use on tactical aircraft.⁵⁵ (See Figure 35)

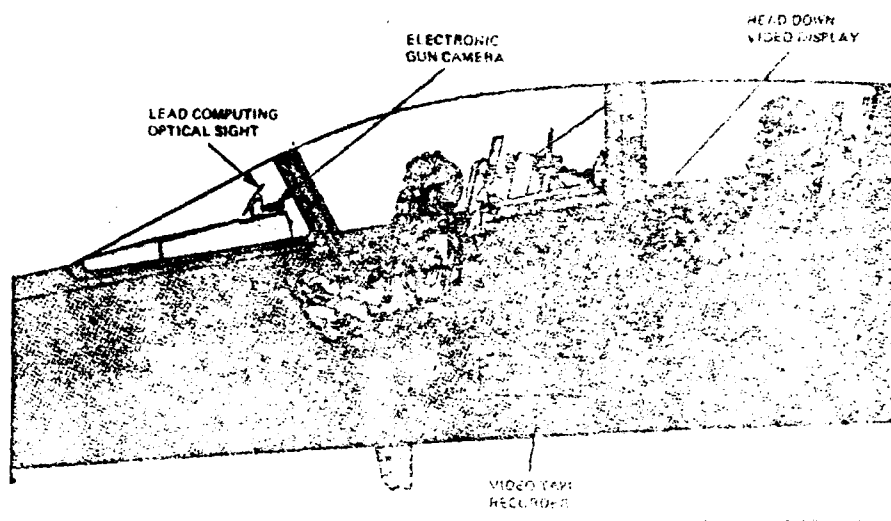


Figure 35

Cockpit Television Sensors (FAIRCHILD)

The CCD is also being evaluated for use with artillery for target location and real time observation of distant battlefield targets. The evaluation used a parachute deployed, all solid state TV camera and radio frequency transmitter mounted in an artillery shell. The concept, if accepted, would be able to provide commanders with

⁵⁵ Fairchild Imaging Systems, "CCD: The Ultimate Shift Register," Electronic Warfare Defense Electronics, USPS 392-670, vol. 11, no. 2 (February, 1979), pp. 1-4.

a view of the enemy approximately 14 KM behind the forward edge of the battle area (FEBA).⁴⁶ (See Figure 36 and 37)

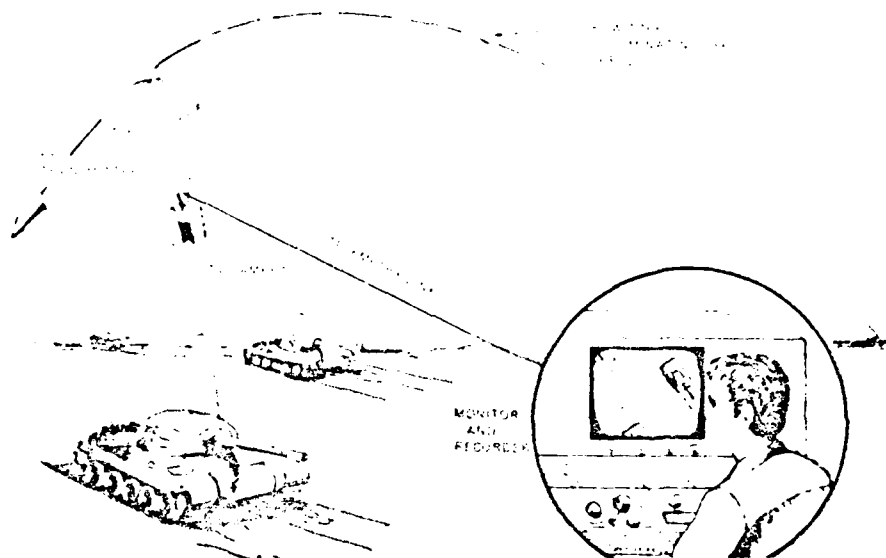


Figure 36

Artillery Application (FAIRCHILD)

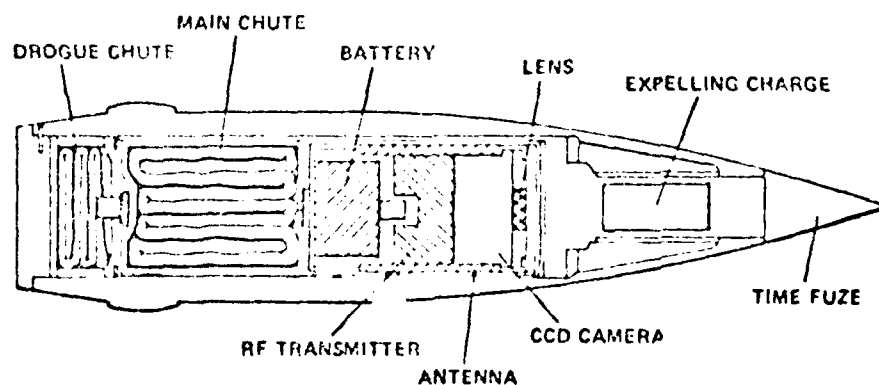


Figure 37

Artillery-Launched TV Package (FAIRCHILD)

⁵⁶Ibid., p. 3.

The CCD has great potential for all applications discussed and work is in progress on a third generation intensifier tube. These new intensifiers are to be called Third Generation Proximity Focus Microchannel Plate (MCP) Intensifiers and are to be used with high resolution vidicon tubes. These intensifiers are reported to provide luminous gains in excess of 100,000 with excellent uniformity.

These new intensifiers are still in the experimental phase, but the military is considering them for training applications.⁵⁷ If the past cycle of development continues, these tubes will be evaluated by the military and then, if proven effective, should be swiftly accepted by the other communities.

The first table (Table 1) is shown to offer the reader a listing of the applications that have surfaced to date, and the second table (Table 2) is shown to offer the reader a quick reference listing the type of sensor and its reported image tube sensitivity. By using Table 2, one could select the correct sensor for a particular application.

⁵⁷ Meacham, loc. cit.

Table 1
Types of Application

Type	Application
<u>Military</u>	1. Night sighting of weapons 2. Night driving 3. High speed photography 4. Surveillance 5. Night flying 6. Ordinance guidance 7. Training 8. Underwater rescue 9. Patrolling 10. Paramedic night work
<u>Scientific</u>	1. Space program 2. Rocket testing 3. Rocket guidance 4. Nuclear reactor inspection 5. Sea exploration 6. TV microscopy 7. Engine analysis 8. Observatory telescope enhancement 9. X-ray intensification 10. Fiber-optic image intensification
<u>Industrial</u>	1. Security 2. Assembly procedures 3. Engine analysis 4. Oil drilling re-entry 5. Oil case pipe inspection 6. Nuclear reactor inspection 7. Welding inspection 8. Quality control on moving parts in an assembly line 9. Observation of dangerous functions 10. Mine rescue 11. Photography 12. Forestry 13. Nocturnal crop dusting
<u>Educational</u>	1. TV microscopy 2. Fluoroscope (x-ray intensification) 3. Nocturnal entomology 4. Night flying 5. Educational research 6. Night training (military and security) 7. Photography 8. Sea studies

Table 1 (continued)

Type	Application
<u>Medical</u>	1. X-ray enhancement 2. Scientific experimentation 3. Cell (fluid flow) study 4. Fiber optic image intensification 5. Low light ophthalmological surgery 6. Retinitis Pigmentosa patients 7. Mine rescue and first aid 8. TV microscopy 9. Instrumentation for experiments 10. Nocturnal observation

Note! This is a very new and ever changing technology, where new applications are surfacing continually. More applications have surely emerged since completion of this study in April 1980.

Table 2
Image Tubes and Their Sensitivity to Light

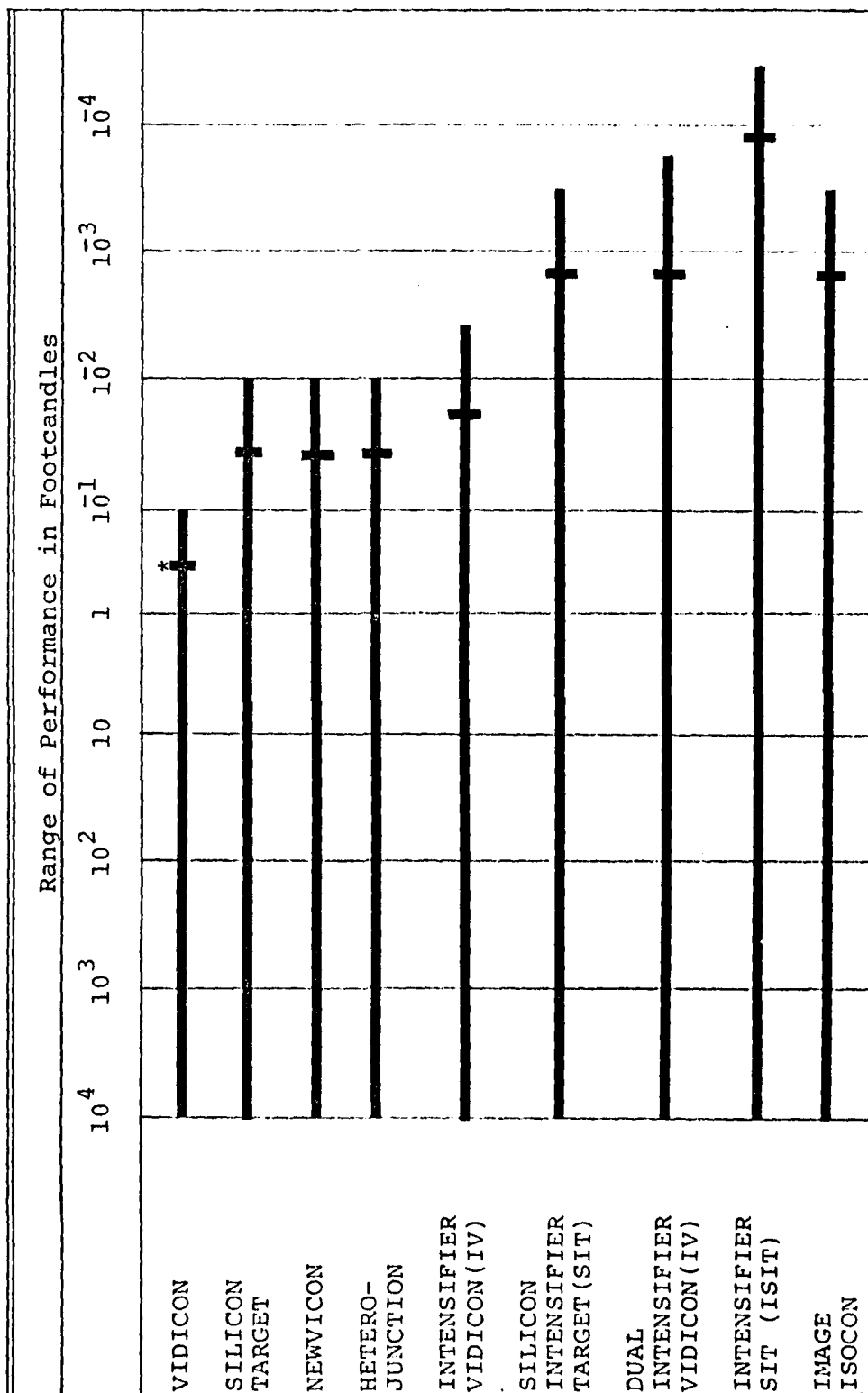


Table 2 (continued)

Range of Performance in Footcandles										
	10^4	10^3	10^2	10	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	
INTENSIFIER IMAGE ISOCON										
COLOR IMAGE ISOCON										

* The break in the right-hand portion of the horizontal bars indicate the limit of full camera performance, while the extreme right-hand edge of the bar indicates approximately the least amount of light that will produce a usable picture. (Chart format from COHU)

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Image intensification is a relatively new approach to allowing man to be able to see in areas of low illumination. Its use was originally developed for the military, but it has also met success in industry, science, medicine and education.

The purpose of the study was to identify applications of image intensifiers in the military, scientific, medical and educational communities and to further identify the types of sensors being produced to date.

The method of the study consisted of four approaches. First, a review of the literature relating to image intensifiers. Secondly a survey was conducted among the manufacturers of image intensifiers to obtain information on sensors and their applications. The survey was done by telephone and 11 manufacturers were contacted. Third, one laboratory, NVL, and one Army test agency, TCATA, were also contacted for input on known sensors and manufacturers. A total of 11 manufacturers sent information or gave it during the telephone call, for a return rate of 100 percent. All information sent and discussed during the telephone calls was included in the study. Fourth, two charts were made to show the

applications identified by the study and the types of sensors being produced at the time of the study.

The results showed that image intensifiers are indeed "catching on" and are being used in all of the communities selected for this study. As has been true with almost all electronic devices, the advent of micro-electronic circuitry and lower power consumption has virtually opened the field for smaller, more efficient image intensifiers.

The majority of the research and development for these devices is still done by the military, or for the military, but as success is gained through the military applications the other communities quickly accept the devices and put them to use supporting their particular needs.

Conclusions

After reviewing the information gathered in the study, the following conclusions have been reached:

1. Image intensifiers are here to stay. They have been very professionally developed over a short period of time with successful and impressive results. They are becoming increasingly more lightweight and are using less power for operation. These two characteristics will cause them to be considered for more applications.

2. The scopes, sights and munitions guidance systems developed for the military have spearheaded the research in this technology. As in most forms of technology, other

applications have been developed as a result of the military successes, to meet the needs of other communities.

3. The devices being developed, are just the beginning of what could change the television camera as it is known today. The CCD will allow cameras to be as small as a cigarette pack and operate on less than 12 volts of power. The lens system may well be the largest part of future cameras.

4. Color cameras will continue to be perfected for use by security and space communities and will surely find a variety of broadcasting applications.

5. Cameras with intensified sensors will surely change lighting techniques in broadcasting as the illumination requirements are decreased.

6. The future of image intensification technology is bright. With the advent of home television systems, and a television oriented society, the market is surely going to grow as did the markets for the pocket computer and the LED watch.

Recommendations

One recommendation is offered regarding application of an image intensifier. It is: That anyone considering the purchase of a television camera, consider purchasing a low light level television camera. The cost will be more, but the savings in illumination costs, temperature control costs (air conditioning to combat heat produced by lighting), and

power consumption will aid in making up the difference. Versatility in application of a LLLTV camera allows it to be used with neutral density filters during the majority of daylight situations, and then without the filters the camera can be used for low illumination applications. This versatility is presently not available with standard television cameras.

Recommendations for Further Study

Two recommendations are offered for further study on the applications of image intensifiers. The two recommendations are:

1. Additional studies should be done on the progress made in image intensifier technology using Charge Coupled Devices (CCD's) and "Micro" electronic components.
2. A study should be done to determine the energy impact of converting present state of the art TV cameras to LLLTV cameras. This study should focus on: Lighting Requirements, Camera Power Consumption, Maintenance and Air Conditioning Costs.

BIBLIOGRAPHY

BIBLIOGRAPHY

Collected Brochures

- COHU, Inc. Closed Circuit Television, Short Form Catalog 6-543. San Diego: Electronics Division, 1976.
- COHU, Inc. High Sensitivity Television Cameras in Low Light Applications. San Diego: Electronics Division, 1976.
- COHU, Inc. 2000 Series System Planning Diagram. San Diego: 1976.
- COHU, Inc. Underwater TV. San Diego: 1969.
- Electro-Optical Systems, Gen III Television System. Maryland: 1980.
- Edo Western. Deep Water Re-Entry Systems. Salt Lake City: 1979.
- Edo Western. High Resolution TV Cameras. Salt Lake City: 1979.
- Edo Western. Underwater Television Systems. Salt Lake City: 1979.
- Fairchild Imaging Systems. Electronic Warfare Defense Electronics. Vol. II, No. 2, 1979.
- Fairchild Imaging Systems. Slow Scan Borehole Inspection TV System. New York: 1979.
- General Electric Corporation. 4TE-37 Nitegard. USA: 1978.
- ITT. Image Intensifiers, 18MM Microchannel Wafers. Pennsylvania: 1972.
- Litton. 18MM Microchannel Wafer Tube Image Intensifiers. USA: Electron Tube Division, 1979.
- Litton. Litton Electro-Optics Department. USA: Electron Tube Division, 1978.
- Litton. Look To Litton For Night Vision Goggles. USA: Electron Tube Division, 1979.

Ni-Tec, Inc. Second Generation Image Intensifiers. Illinois: 1977.

Panasonic, CCTV Cameras WV-1000A Series. Japan: 1978.

RCA. Closed-Circuit Video Equipment, Camera TC1160. Pennsylvania: 1976.

U.S. Army Electronics Research and Development Command Night Vision and Electro-Optics Laboratory. Night Vision. Virginia: 1979.

VARO Electron Devices, Inc. 25MM MCP Intensifiers, Model 3603. Texas: No Date.

VARO Electron Devices, Inc. 1979 Personnel Planner. Texas: 1979.

Westinghouse. Modular Television Camera Series. Maryland: Systems Development Division, 1976.

Westinghouse. Subminiature Television Camera. Maryland: Defense and Space Center, No Date.

Sources Consulted

Edo Western. "1633 Sit TV Camera Exploring the Universe," The Flying Fish, Fall, 1976, p. 10.

Ford, M. J., R. E. Honeycutt, R. E. Nordland and W. N. Robinson. "Advanced Optical Blade Tip Clearance Measurement System," Abstract of NASA contract 159402, FR10200A, July, 1978.

Headquarters, Department of the Army. "Army Model UH-1C/M Helicopter," TM55-1520-220-1011, Washington, D.C., 1970, pp. 1-2 through 6-6.

Headquarters, Department of the Army. "Night Vision Sight Individual Served Weapon," TM 11-5855-203-10, Washington, D.C., 1967, pp. 8-9.

Holthaus, J. E. and J. Meacham. "LLLTV" (Paper presented at Electro-Optical Systems Design Conference, New York, N.Y., September, 1969).

"Image Devices IMD-100," RCA Products Guide, Pennsylvania, 1979, p. 5.

"Imaging Devices SA-110," Westinghouse Produces and Applications Booklet, New York, No Date, p. 4.

Johnson, Ronald E. "Optical Engineering of First and Second Generation Automatic Tracking/Laser Designator Pods" (Paper presented at the Society of Photo-Optical Instrumentation Engineers Symposium East, Washington, D.C., March 1978).

Kay, David B., James L. Cambier and Leon L. Wheels Jr. "Imaging in Flow," The Journal of Histochemistry and Cytochemistry, Vol. 27, No. 1: 329-334, 1979.

Lynch, Thomas F. "Development of Intensified Charged-Coupled Devices (CCD'S) and Solid State Arrays" (Paper presented at the Society of Photo-Optical Instrumentation Engineers Symposium East, Washington, D.C., March, 1978).

Meacham, James H. "Television For Night Training Scenerios" (Paper presented at the Interservice/Industry Training Equipment Conference, Orlando, Florida, November, 1979).

Orell, Patrick H. "Low Light Level Television as an Aid to Army Night Training" (Paper presented at the Society of Photo-Optical Instrumentation Engineers Symposium East, Washington, D.C., March 1978).

Orell, Patrick H. "Scoring Tank Gunnery by Instant Replay," Armor Magazine, May-June, 1977, pp. 23-24.

Prell, James A. "Basic Considerations for Assembling a Closed-Circuit Television System," Nuclear Regulatory System NUREG-0178, Washington, D.C., 1977, p. 3.

Vicars-Harris, Michael. "A Solid State (CCD) Cockpit Television System" (Paper presented at the Military Electronics Defense Expo, Rhein-Mein Halle Wiesbaden, W. Germany, September, 1979).

AD-A088 165

ARMY MILITARY PERSONNEL CENTER ALEXANDRIA VA
APPLICATION OF IMAGE INTENSIFIER TECHNOLOGY TO THE MILITARY, SC--ETC(U)
MAY 80 P H ORELL

F/G 9/1

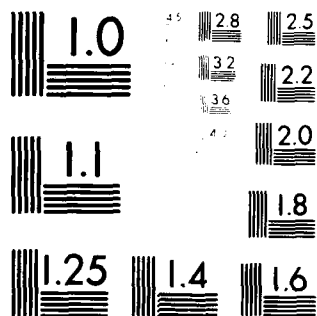
UNCLASSIFIED

NL

2 of 2



END
DATE
FORMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

APPENDICES

APPENDIX A

Subject: The format of the interviews and requests for information, made by telephone.

Good Morning/Afternoon

My name is Pat Orell and I am a graduate student at the University of Wisconsin, Stout. I am presently writing my thesis on the subject of image intensifiers and received your company's name from the Night Vision Labs as a manufacturer of (image intensifiers) or (low light level television cameras).

I am calling to request any brochures, manuals, papers or other material that I can use to identify sensors and applications of those sensors to the military, scientific, educational, industrial and medical communities. I have received a packet from the Night Vision Labs that has information on military scopes and sights, but could use any other material you can send on military hardware and applications.

The paper will be footnoted and your company will receive proper credit for its contributions to the technology. I am also prepared to reimburse you for any mailing cost incurred in your assisting me in this study.

My address is - - -

Thank you for your assistance in this endeavor and I look forward to reading your input to the study.

APPENDIX B

The following is a list of the companies who were contacted and contributed to this study:

COHU, Inc.

Edo Western

Fairchild

General Electric

ITT

Litton

Ni-Tec

Panosonic

RCA

Varo

Westinghouse

Note! Westinghouse requested that the paper state that they are a government contractor only.