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NIGHT VISION DEVICES

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FOREWORD

Science has greatly influenced and is continuing to influence human life, and there is always an inquisitive instinct of the people at large to know more and more about what science is, what it has done and what it is expected to do tomorrow. Applied science is the fountainhead of technology and abstract ideas steadily find their way to practical applications. Science has grown so vast and the various scientific disciplines so interdependent on one another that persons belonging to one area of specialization cannot afford to ignore developments in other areas. Therefore, there is increasing emphasis on popularization of science. Even specialists have to constantly look for literature in disciplines other than their own. This is true for persons in Defence too. For instance, an overall acquaintance with scientific developments will help the soldier to know and use his weapons well and play his role effectively.

Popularization of science is imperative if we want our people to develop the habit of rational thinking and behaviour. Popular Science & Technology (PST) has two major objectives: (i) to create general awareness among its readers, and (ii) to present in a simple language overviews on topics of current interest. In the current issue, an attempt has been made to present some of the basic principles of 'night vision devices' in a simple style with illustrations, wherever necessary and their applications, particularly of Defence interest, and provide a glimpse into the newer vistas, rather than to cover the complexities and intricacies of this vast subject. Among the diverse topics of military science, the one that seldom gets coverage in popular science journals but which nevertheless is the spearhead of all instrumentation and weaponry, is the subject of night vision technology. The capability to detect and identify targets at night and under poor visibility conditions has been an essential military requirement for a long time. In recent years, the advent of passive night vision devices has added a completely new dimension to tactical operations, not just for the individual soldier, but for almost every component of the tactical spectrum.

It is hoped that this special issue would stimulate interest and curiosity of the reader; familiarize him with the outlines of the subject; and inculcate in the younger generation an abiding sense of awareness and enthusiasm for topics of Defence interest.

Delhi
June, 1985

(S.S. MURTHY)
Director

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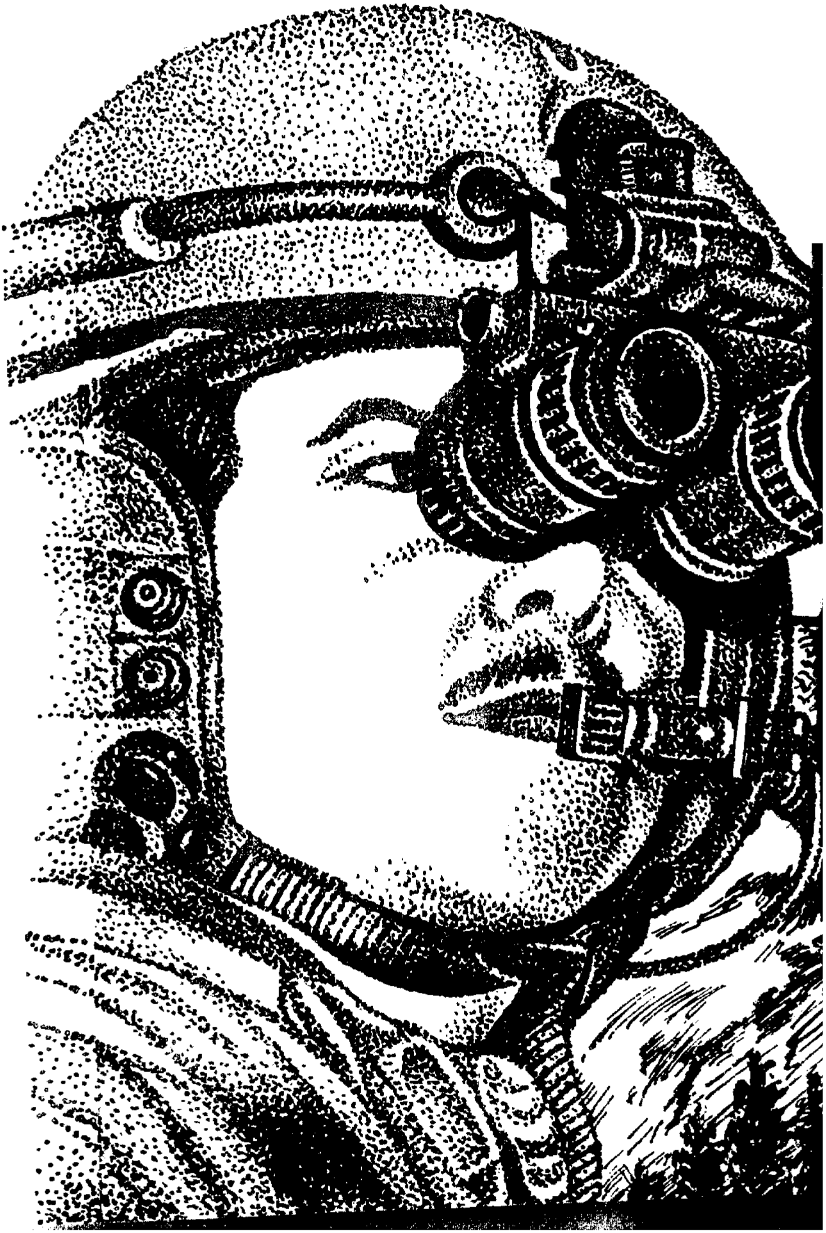
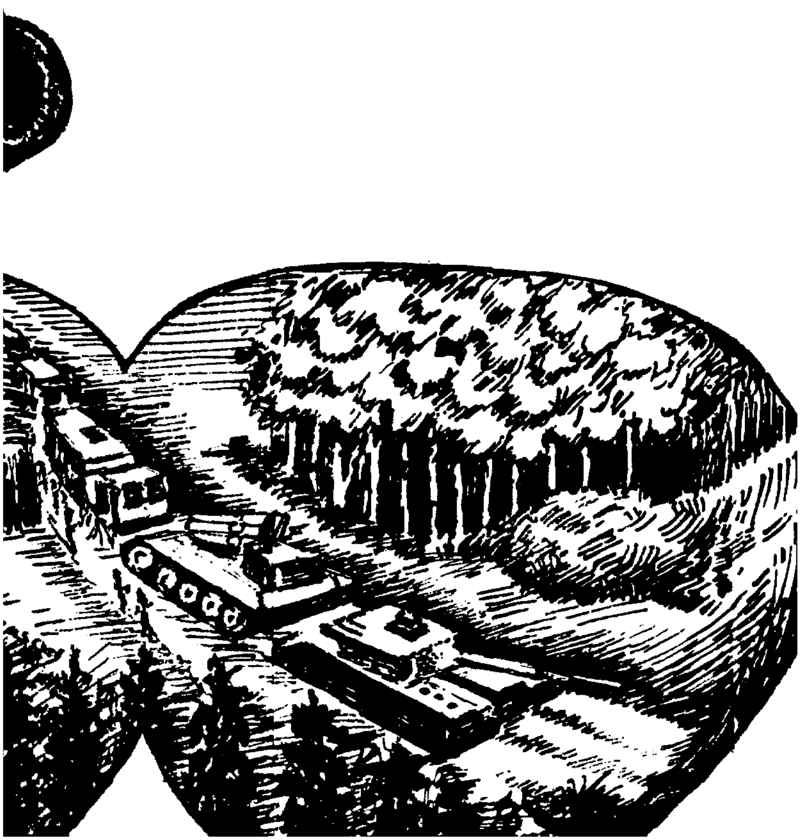


Beat the Dark in Maximum Viewing Comfort



Is Your Night Vision as Resolute as Your Will to Survive ?

For mutual uplift, education and research should go together. *Just as* education cannot improve in quality without research, so research cannot raise its standard of excellence *unless* it is backed by education of the highest quality. The endless cycle of ideas and action, endless invention, endless *experiment*, brings knowledge of motion but not of stillness.

– *Eliot*

1. NIGHT VISION TECHNOLOGY

1.1 Introduction

Night vision signifies the ability to see at night. This capability is normally possessed by owls and cats, but modern developments in science and technology have made it possible to develop devices which enable humans to see in the dark as well as under inclement. Weather conditions such as fog, rain, snow, etc. They are based on simple principles of optics.

The muscles on either side of the lens in the human eye have the ability to stretch or contract automatically, depending upon the intensity of light falling on the eye. When we go out in bright sunlight, the pupil gets contracted. Alternatively, when we enter a shaded room, till such time as the muscles can relax and make the aperture of the eye lens big enough to allow sufficient amount of light to pass through, the objects in the room appear blurred. Despite this versatility of the human eye, it has its limitations. The muscles cannot increase the aperture indefinitely. Therefore, in poor light we are unable to see the objects because the image cannot be formed on the retina clearly.

To improve the situation we fall back on science. Developments in electronics and optics have made it possible to design and construct opto-electronic devices which intensify the image. Just as microscopes and telescopes' help us to view small objects by magnifying their images, these devices help us by forming intensified images not visible to the naked eye because of the insufficient light reaching it from the objects. They enhance the perception of the eye by forming brighter images.

The capability to detect and identify targets at night and under poor visibility conditions has been an essential military requirement for a long time. The modern army's need to operate at night and under conditions of extremely poor visibility has led in recent years to major advances in the development of night vision devices. Since the soldiers have to often fight in the dark at night, they have to face a severe stress as far as the location of target is concerned. So when it comes to providing an army with uptodate and sophisticated night vision capability, the choice of which components to use is often a crucial issue. Considerable amount of research has been done in this field and as a result, a wide range of night vision devices, embracing many diverse technologies, is now available.

Night vision technology has given a completely new dimension to tactical operations, not just for the individual' soldier, but to almost every component of the tactical spectrum, ranging from the rifleman to helicopter pilots and tank drivers. Apart from the various applications calling for the exploitation of diverse technologies, the time domain in which one is thinking also plays an important role. For current use one takes current technologies; for five or ten years hence one takes technologies that are well advanced in development and where the manufacturing processes are more or less defined. Highly advanced technologies are left for the future. Research and Development work has to be progressed to meet the immediate, short-term and long term requirements. One will be left with an under-developed fighting force if one decides to wait or postpone work on future technologies.

Night vision systems encompass all intensified night sights from the self-contained rifle sight to the complex . multi-channeled vehicle sight. Very few among the users of such systems may have given much consideration to the component that is the heart of all these sights, namely the Image Intensifier. This component is in fact the night sight user's window on the world under darkness. It is, therefore, necessary to have a comprehensive programme of image intensifier development and production aimed at fulfilling the needs of a wide variety of highly demanding night vision applications. While a number of reputed manufacturers of night vision equipment have shown some reluctance in applying advanced technology in quantity production in order to first break even on first or second generation image intensifiers, generation three is already nearing production maturity. One manufacturer who is preparing to launch production of third generation image intensifiers in English Electric Co. Ltd. of Chelmsford, Essex (UK).

1.2 Image Intensification

Electronic image intensification began in the early 1930s but became more widely available in the 1950s with the introduction of the infrared image converter tube. In this device, a silver-oxide caesium (Ag-O-Cs) photo-cathode (designated type SI) is used. The sensitivity of this photocathode is low and its thermal emission is rather high; so the tube can usefully operate only if the scene itself is illuminated" with infrared radiation; that is why the devices using this type of tube are termed active. Need for a separate, powerful infrared floodlight makes the system rather cumbersome and awkward to use. A serious drawback of the image converter tube for military applications is that an enemy with a similar viewer can easily spot the source, with obvious consequences. To overcome the disadvantages of the image converter tube, much research went into developing photocathodes with higher sensitivity and lower thermal emission. This led in the sixties and early seventies to the introduction of first generation passive image intensifiers.

1.3 Advantages of Night Vision Devices

The human eye is a very sensitive and versatile image detector but has a number of physical limitations. An electronic image intensifier can provide a fundamental improvement and perception gain over the unaided eye by capturing more photons from the scene and using these more efficiently. More photons are collected by employing an objective lens of larger diameter than that of the pupil of the dark-adapted eye. The only limitations in this respect are the practical considerations of size and weight of the instrument depending upon the application. The co11ected photons can be used more efficiently by detecting them with a higher quantum efficiency than that of the retina. The most suitable type of detector for this purpose appears to be a photoemissive cathode consisting of a compound of the alkali metals: sodium, potassium and caesium with antimony. Surfaces of this kind have quantum efficiencies of upto about 20% for white light and can make much more efficient use of the night-sky radiation than the retina. On the other hand, an increased integration time beyond the 0.2 second of the fully dark-adapted eye is only of limited use in practical applications because it reduces the ability to detect moving objects which appear to become more as and more blurred. It is thus possible in principle to obtain considerable improvement in perception over the dark-adapted eye by employing an instrument with a large diameter of its objective lens and an efficient photocathode. However, this potential perception gain can be achieved in practice only if the detected photons in the form of emitted photoelectrons produce scintillations on a final viewing screen that are bright enough to be registered on the observer's retina. This condition leads to the requirement of a minimum amount of light amplification or lumen gain in the instrument. Such a lumen gain can be achieved with the aid of image-intensifier tube. Much research has been done, especially in the fields of electronic image intensifier tubes, as well as optical technology relating to the optical components of a night vision system (i.e. the objective lens and the magnifying eyepiece) with a view to making the performance these night vision devices better and better.

1.4 Image Intensifier Tubes

In the Night Vision Systems using Image Intensifier (I.I) Tubes, the targets are illuminated by natural radiation a sources (star, moon, etc) and the light reflected from the target is collected by the objective lens of the system. The low-light image is formed at the photocathode of the image intensifier tube which forms an amplified visible image at the phosphor screen. In the cascaded three stage I.I. tubes, the visible image formed at the phosphor screen of the first module is further amplified by the second and third modules. In second generation tubes the required amplification is achieved by using micro-channel plate just before the phosphor screen. By either of these arrangements, it is possible to get sufficient amplification which gives a good presentable visible image at the final phosphor screen.

The performance of these passive devices depends upon various parameters like reflectivity of the target, light gathering power of the objective and characteristics of I.I. tubes. These tubes should have high light amplification to encounter very weak night illumination. The amplification of an I.I. tube depends upon photocathode luminous and radiant sensitivities, phosphor screen efficiency, and applied voltage. The phosphor screen efficiency cannot be improved beyond a certain limit. Voltage also plays a significant role in increasing the gain of the image tube as the gain increases with increase in applied voltage, but if the voltage is increased too high, internally generated noise will begin to affect the low-light-level image quality. Hence, only the photo-cathode sensitivities can be improved upon to enhance the performance of I.I. tubes. In the spectral distribution characteristics of moon light and star light, it is quite clear that the available energy of star light is more in the near IR region. Over the past three decades imaging devices have been developed with sensors, not only significantly more sensitive than the human eye, but also extending imaging capabilities into wavelength region outside the visible region. It is advantageous to use photocathodes which are more sensitive in the near IR region, as green vegetation has high reflectivity in this region, which leads to a considerable improvement in the contrast for natural scenery. Gallium arsenide (GaAs) photocathode developed recently and incorporated in third generation I.I. tubes has shown a remarkable improvement in every respect. For quantitative assessment of the photocathodes (PC), their luminous sensitivity (LS) and radiant sensitivity (RS) are normally specified. The measurements of LS and RS can be made on single stage intensifier tubes, or on the first stage module of cascaded, I.I. tubes prior to attaching the high voltage oscillator multiplier assembly. Luminous gain (LG) does not give a complete idea of the performance of I.I. tubes under star light conditions. Keeping this in view, a new measurement called 'Radiant Gain' (RG) has been introduced in the specifications, which gives sufficient information about the performance of I.I. tubes under star light conditions. Greater the value of RG, better will be the performance of I.I. tube. It has been the general experience that tubes with a lower luminous gain but a high RG/LG ratio performed better than tubes with a high luminous gain and lower RG/LG ratio.

The screen luminance not only depends upon the input irradiance, but also on second and third stage amplification in first generation cascaded I.I tubes and amplification by micro-channel' plate in second generation micro-channel inverter and proximity tubes.

1.5 Role of DRDO

Present day war logistics demand sighting and vision capability both during day and night, and under all conditions of weather and terrain. Laboratories under DRDO and its predecessor organisations have all along been contemporary in their approach and their work has been representative of the state-of-art in the field. A large number of conventional optical instruments were successfully developed for use with weapons during the early stages. The potential of IR based instruments was realized by DRDO quite early side by side the other research centres in the world, and work was taken up on Infrared Optics when the first IR sensors became commercially available. IR radiations which are thermal and invisible obey the laws of visible light rays for vision and photography. With suitable devices, the IR radiations can, thus, be used for seeing through the darkness. A lot of work has been done on the development of sensors and today more and more efficient and high performance detectors covering most of the IR range are available. DRDO has kept itself abreast of the latest developments in the field and having successfully developed the active IR and passive Systems, embarked upon development of more sophisticated complex passive instrumentation, thermal imaging and the low light level television systems.

The whole gamut of research and development involves conceptualization of systems, formulation of specifications, development of technologies involved, creation of facilities for production and evaluation, development of prototypes and subsequent technology transfer. The process of research and development in this field of Electro-optical instrumentation constitutes a highly specialised activity involving the scientists, technologists and, of course, the users.

The first in the series of electro-optical instruments' for night vision application were the active IR devices which were designed and developed indigenously for the Vijayanta tank.

Active night viewing devices require infrared IR sources for illuminating the target. These sources are obtained by the use of infrared filters placed in front of normal intense lamps, which filter out more or less all the visible radiations but transmit infrared radiations. To avoid dependence on foreign sources and to achieve self-sufficiency in respect of this strategically important component, work on the development of suitable filters was taken up at the Instruments Research & Development Establishment (IRDE), Dehradun.

Keeping in view the functional and operational requirements, a suitable composition has been developed to make IR filters by casting film on a glass substrate. Filters have been made using indigenously available toughened glass plates. Their performance under actual field/temperature conditions has been found entirely satisfactory. IRDE has also developed a suitable composition to facilitate repairing of existing IR filters. The technique of repairing has been standardized and perfected.

Next in the series of night vision systems came the passive night devices, which unlike active IR devices, are not exposed to detection, as these depend for their operation on ambient light available in the battlefield and placed do not need an artificial source of illumination. Many types of devices have been successfully developed for use by the artillery, infantry and armoured corps.

Passive night vision devices like Passive Night Sight for Anti-tank weapon, Passive Night Observation Device for Arty OP, Passive Night Vision Binocular and Driver's Passive Night Periscope for Vijayanta have been successfully developed by Instruments Research & Development Establishment (IRDE), Dehradun and are under production at different production centres in public/private sector.

Concurrently, work is in progress on the design and development of low light television systems for tanks and helicopters. The third area of night vision instrumentation pertains to Passive Infrared. These instruments are of recent origin even in the advanced countries of the West, but because of their strategic importance, they are considered vital for future armament. DRDO initiated work in this field only a couple of years back and has achieved satisfactory progress. A thermal imager for use in Main Battle Tank (MBT - 80) is in advanced stage of development.

Image Converter and Image Intensifier tubes are the heart of active IR and passive instrumentation respectively. Development of I.I. tube technology has passed through a series of stages from cascaded Image Intensifiers to micro-channel plate based wafer systems. The sensor materials have also undergone various stages of development. Instruments Research and Development Establishment, Dehradun under DRDO which is the pioneer in this field, took up the formulation of specifications and creation of evaluation facilities for this vital sensor for the first time in the country. The efforts and competence of this organisation have been appreciated by all the leading manufacturers of these devices. Facilities are available for the evaluation of various parameters like Luminous and Radiant Gain, Reso1ution, E.B.I. Maximum Screen Luminance, Magnification, Distortion, Recovery Time, etc.

A Transfer Technology Centre has been set up at IRDE for transferring the new technologies involved in the electro-optical, night vision, laser and servo based instruments developed at IRDE. In the first instance, the Centre has taken up the transfer of technology of three electro-optical night vision and two laser based instruments. Planning is being done for the technology transfer of servo based and thermal systems also. The night vision devices taken up by TTC in the first instance are (i) Driver's Passive Night Periscope for Vijayanta, (ii) Passive Night Vision Binocular, and (iii) Passive Night Observation Device of Arty OP. The Technology Transfer Centre has made a good start and interacted closely with the production agencies in getting the jobs executed. Regular guidance is given by TTC to the production agencies in the manufacture of critical assemblies and components.

The success achieved in the field of Passive Night Vision Instrumentation, including LL TV system, has been possible as a result of successful establishment of related technologies in the field of optical processing, thin film coating, optical evaluation, image enhancement, etc.

I distrust all immense specifications ....
Truth I believe will be found to be shaped like
a tree and not like a telegraph pole.

J.B. Priestly

2. INFRARED OPTICS

Infrared rays are invisible light rays having wavelength larger than that of ordinary light. Being essentially thermal radiations, all objects existing above the absolute zero emit such rays. The temperature difference between the objects and their surroundings enables the detection of targets. Infrared radiations being invisible do not reveal the position of the observer when used to illuminate the target. Though the infrared part of the light spectrum was first detected about 175 years ago, yet it was only during the Second World War that its military applications were contemplated. Germans used this special device first for secret signaling for the surveillance of the enemy tanks hidden in darkness and for the detection of bombers which confused radar detections.

2.1 Use in Defence and Industry

Infrared devices have been developed for use of services. These are either "active" devices or "passive" devices. In active devices, the user carries a source of infrared radiation and illuminates the target with invisible light. These devices are invariably image forming; the infrared image of the target is converted to a visible image with the help of a suitable device. In passive devices, the natural and characteristic emissions from the targets are utilized for the detection of the target. These are essentially non-image forming type.

The passive devices find use in missile guidance, bomber defence, communication systems, satellite tracking, etc. A typical example is an I.R. air-to-air missile guidance system. In this, infrared radiation from the tail pipe of the jet engine of enemy aircraft under pursuit is collected and focussed by means of an optical system on a suitable detector. The electrical response from this detector is amplified adequately and fed into a servomechanism which operates the controls of the guidance. A change in the path of the plane under pursuit results in a differential input to the servomechanism and controls the path of the missile. The missile is, therefore, suitably guided to hit the target at the correct location and destroy it.

Infrared devices are also being used in various industrial processes, e.g., automatic monitoring of chemicals and control in the manufacture of textiles, plastics and metals production, fire detection, collision avoiding systems, room heating systems, retreading of tyres and photographic industry.

2.2 Infrared System

Whether the I.R. device is for military use or for civilian use, the system in all cases consists of six basic units (a) source of radiant energy, (b) an absorbing medium, (c) an optical system, (d) a filtering system, (e) a detector of radiant energy and (f) presentation of output by which the data are made available to the operator or observer .

In the military equipment, the source of radiation is the target itself seen against a background of sky or a ground with thermal discontinuity. The absorbing medium is the atmosphere which introduces a serious limitation upto an altitude of 30,000 ft. However, this is not a source of serious trouble at higher altitudes. The role of the monochromator part of the optics is played by filtering techniques to eliminate the background noise. The optics focus the incident radiation on the detector. The data are presented either by visual image formation or by electronic methods with suitable amplifiers, transducers and servomechanisms operating the final controls. Filters in I.R. systems are intended to enhance the target to background contrast by transmitting wavelengths where target radiation is strong, and reflecting or absorbing where the background is strong. Detectors are of two types: Thermal and Photon. Thermal detectors make use of the heating effect of I.R. radiation and photon detectors measure the rate at which the quanta are absorbed. Photon detectors require incident photons to have more than a certain minimum energy before they can be detected.

I.R. devices are now extensively used in fire control to perform the functions of "search", acquisition and "tracking". The search function implies a systematic identification of the targets of interest. This can be alternatively called 'scanning' or 'snooping'. Infrared guidance systems are now gradually supplementing or higher replacing the radar.

When a true genius appears in the world,
you may know him by this sign, that the target
dunces are all in a confederacy against him.

Swift

.............scientific work must not be considered from
the point of view of the direct usefulness of it.
It must be done for itself, for the beauty of science,
and then there is always the chance that a scientific
discovery may become a benefit for all humanity.

Madam Curie

"...........Human reason has discovered many amazing
things in nature and will discover still more,
and will therefore increase its power over nature........,"

V.I. Lenin

A nation cannot progress if it merely imitates its
ancestors; what builds a nation is creative, inventive
and vital activity, I seek the creative mind.

Jawaharlal Nehru

3. PASSIVE IMAGE INTENSIFIERS

Much research on night vision systems went into developing photocathodes and microchannel plate (MCP) in order to overcome the disadvantages of the image converter tube. This led to the development of first, second and third generation passive image intensifiers.

3.1 First generation "passive" image intensifiers

The major factors which favoured introduction of passive night viewing were the development of the tri-alkali photocathode (designated type 525) and of fibre-optic windows, by virtue of which the scenes could at last be viewed under star light conditions.

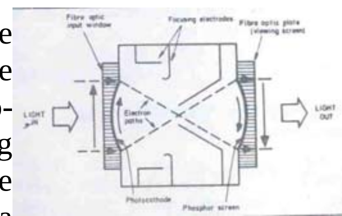
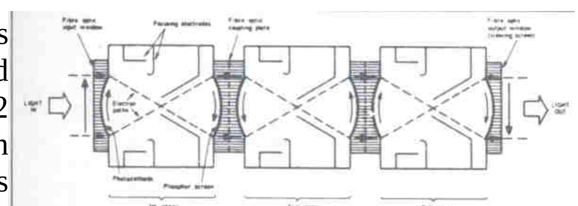


Figure I shows a section through a first generation passive image intensifier tube. Electrons emitted by the photocathode are accelerated by a g voltage of about 15 kV and electro-statically focussed onto the phosphor screen. The resulting image produced on the screen is viewable directly through the exit window usually via a magnifier. The brightness gain of a tube depends on factors such as photocathode sensitivity, accelerating voltage and tube magnification. With a magnification, of less than unity such a tube can provide a brightness gain of about 2000, which is sufficient for a driving sight under star light conditions.



To provide a useful magnified image as required in aiming sights, the tube should have a gain of at least 10,000. Figure 2 shows the Cascade tube in cross-section consisting of three first generation tubes connected by fibre-optic couplers, and it easily provides such gains. Though Cascade tubes with integral power supplies have been used extensively in the field for many years, they have some disadvantages (i) they are rather heavy and bulky and are usually limited to applications in which portability is not a prime consideration (e.g. gunner's and commander's sights, observation sights); (ii) on account of several phosphor screens, they suffer from noticeable image persistence which can be highly distracting with moving scenes, thus causing bright tracks on the screen; and (iii) they suffer considerably from highlight blooming (a single highlight causing complete white-out of the image) and the phosphor screens themselves can be damaged by excessive highlights in the scene.

The development of the micro-channel plate (MCP) solved most of these problems and led in the seventies to the introduction of second generation passive image intensifiers.

3.2 Second generation "passive" image intensifiers

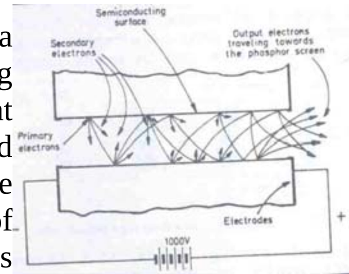
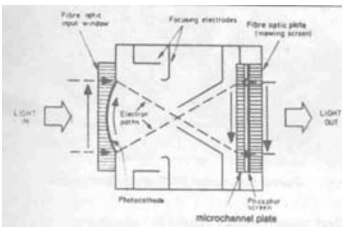


Figure 3 shows the principle of the MCP which comprises a two-dimensional array of minute glass tubes. Electrons striking the inner surface of the tubes release secondary electrons that traverse the tubes under the action of a biasing voltage and release other secondary electrons. This produces an avalanche of electrons. The net result is an increase in the number of electrons at the output of the MCP, i.e. the input signal is amplified. Also shown is a section through an inverting MCP image intensifier .



The double proximity-focussed MCP image intensifier (Wafer tube), a cross-section of which is shown in Figure 4, provides even greater size reduction than the inverting tube. In the wafer tube, the MCP is located immediately behind a flat photocathode at a distance faces of a few tenths of a millimetre. With such narrow spacing, no more than about 200V is needed across the gap to give a good image. The tube usually incorporates a fibre-optic twister in order to produce an erect image. Wafer tubes are light and compact and are most suited to applications where portability is of major importance (e.g. in goggles). However, they are more susceptible than inverter tubes to photocathode damage; so special means must be provided to afford them protection.

3.3 Third generation passive image intensifiers

These tubes, also based on the MCP, use negative affinity photocathodes produced from elements in groups III and V of the Periodic Table, such as caesiated gallium arsenide. They are more sensitive than first and second generation tubes and are capable of higher resolution, which means that they can operate effectively at a somewhat longer range. Their use will probably be limited to special applications {e.g. helicopter pilot's goggles) on account of exorbitant cost.

3.4 Intensified Vidicons

In the intensified vidicon, a TV camera tube is combined with a first or second generation image intensifier . The device may be an integral unit - as in the intensified silicon vidicon or ISV -with the image intensifier (first generation) and camera tube contained within the same vacuum envelope. The ISV includes a special target {the silicon intensified target or SIT) that responds to electrons. The tube provides gains upto about 2000 over conventional vidicons but, like first generation tubes, is not immune to highlights. Although intensified vidicons have achieved all that could reasonably be expected of them in the way of performance, they have not found general acceptance in military applications or various reasons.

The National Bureau of Standards, Washington (USA) is developing standards for image intensifier night vision devices for use in law enforcement. The quality of the image produced by such devices is an important measure of their utility and image quality criteria are an important part of such a Standard.

An objective image evaluation of image intensifiers consists in measuring the parameters that affect detection or recognition probabilities. The most important parameters are the cathode sensitivity, the noise figure, integration time constants and image transfer characteristics. The first three parameters have no equivalent in optical systems. To qualify image transfer characteristics in optical systems, the concept of the optical or modulation transfer function is well established.

More compact second generation electrostatic and wafer type tubes opened new opportunities for light-weight system designs. For the eye-piece performance and characteristics of the newer magnifier eyepieces, Night Vision Laboratories have developed new methods of testing and criteria for specifications that require considerably better correction than had previously been required. The most recent innovation in 'the field of direct view night vision devices has been that of the Biocular eyepiece.

The method of integrating a biocular eyepiece to a scanning mirror thermal system has the added advantage of modularity, since the biocular eyepiece and diode tube can be used as a retrofit replacement for an existing monocular eyepiece with no optical redesign required of the thermal system. The biocular/diode eyepiece with its large exit pupil provides a significant reduction in the eye fatigue generally associated with the prolonged use of a monocular eyepiece.

There are limits to the performance of image intensifiers for night vision with reference to human eye ability due to the loss of information content associated with light intensification. Other limits are due to the quantum yield and the statistical fluctuation of the number of incident photons.

The features of microchannel plate (MCP)/inverter image intensifiers (high brightness gain, small size, low weight, low image distortion, high output brightness and gateability) make them useful than in many low-light-level applications. It is believed that MCP applied research and development will result in cheaper and more useful low-light-level MCP image tubes in the future.

Channel plate image intensifiers, though primarily designed as viewing aids, are particularly suitable as photographic aids because of their high luminous gain and ability to be gated on and off rapidly. Two cameras are designed around this kind of tube: one for surveillance and security purposes, and the other for projectile photography.

Accumulated combat experience and new research and 'development efforts in the field of low-level night flight have demonstrated an improved capability in night flight, using either selected specialists without night vision systems or a wider group of aviators aided by night vision goggles. The electroluminescent formation flight lights and rotor-tip lights have greatly increased safety in formation flights at night. But each approach has been hampered by design limitations in display panels, poor lighting quality and poor lighting control in the aircrew stations. Landing in dark unimproved areas, navigation over unfamiliar terrain and target acquisition also present special problems which have not yet been completely overcome.

The capability of attacking targets under all-weather conditions both by day and by night requires integration of the corresponding target locating and guidance systems in air-to-surface and air-to-air armaments and equipping the aircraft with appropriate high sensors. For example, an F-15 equipped with the Hughes ANI APG-63 radar are with SAR (Synthetic Aperture Radar) would be able to stay in operation for 95% of the time under extreme Central European winter weather conditions.' In this case, detailed topography maps would be produced by the AN/APG-63 sensor' for display in the cockpit and moving objects such as tanks and trucks would be pointed out to the pilot by blinker signals. In comparison with this, a FLIR-equipped fighter aircraft would be in operation only for 59% and a daylight-only weapons system for 20% of the time. In the field of day night and bad weather target acquisition and guidance systems for air-to-surface armament, high-definition thermal-imaging seekers, radiometric area correlators, etc. are in various stages of development. If weather systems and ammunition are special designed for all-weather duty, they are less threatened by terrestrial anti-aircraft units, since only a few such units can be described as fully capable all-weather systems without limitation.

The real danger is not that machines will begin to think like men but that men will begin to think like machines.

Sydney J. Harris

It is science alone that can solve the problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people. Who indeed can afford to ignore science today? At every turn we have to seek its aid. The future belongs to science and to those who make friends with science.

Jawaharlal Nehru

4. THERMAL IMAGING

All matter above absolute zero emits thermal energy. Much of this energy is absorbed and scattered by the atmosphere. Military thermal imagers, which must achieve maximum range under adverse weather conditions, usually work with sensitive detectors. Here only those thermal imagers will be considered that have found or are likely to find application in military night-vision systems.

4.1 Cadmium Mercury Telluride (CMT) Infrared Detectors

Most infrared detectors used in military applications are photodetectors that exploit the photoconductive properties of CMT, an intrinsic semiconductor, that has to be operated at low temperature. In the schematic operation of an opto-mechanically scanned CMT infrared detector system, an arrangement of horizontally and vertically vibrating or rotating mirrors scans an image of the scene across an array of CMT cells biased at a few milliamps. Infrared radiation emitted by the scene impinges on the cells; This changes their conductivity which in turn modulates their voltage in accordance with the intensity profile across the scene. The composition of CMT can be adjusted to attain maximum sensitivity in either of the two atmospheric windows. The detector elements must be mounted in a glass or metal dewar designed to fit closely over a cold finger. Detectors such as the MIRPY that operate in the 3 to 5 u m band are often cooled thermo-electrically with the elements enclosed in an evacuated capsule; they are consequently light and easy to run. A recent important development known as SPRITE (Signal Processing In The Element) uses an elongate detector element to replace an array of discrete elements. The new SPRITE detector dramatically reduces the number of leads from the encapsulation and simplifies the delay and summation circuitry. However, it does require a specifically designed scanner. Because delay and summation of the signals are performed within the detector itself, the electronics normally associated with these functions can be dispensed with. Furthermore, the number of connections between the element and the outside world is drastically reduced, thus simplifying dewar construction. With fewer components than in a conventional system, reliability is greatly enhanced.

4.2 Pyroelectric Vidicons (PEVs)

These are infrared sensitive TV camera tubes that form a TV image of the scene from the heat radiated by it (bolometric detection). Compared with CMT infrared detectors, PEVs have two important advantages: they do not use opto-mechanical scanning systems and they do not need cooling. PEVs in fact respond not to static images, but to temporal changes in the heat distribution of a scene. So they need chopping or are suitable for observation systems designed to respond merely to scene changes, intruding alarm systems, for example.

4.3 Image Orthicon

This is one of the most complicated camera tubes and can operate at very low light levels. It basically consists of an image section, a scanning section and a multiplier section. In the image section, the light image of the object is focussed on photo-emissive layer and the photoelectrons emitted are brought to focus on a target by a magnetic field.

4.4 Image lsocon

This is an improvement over the image orthicon. Here, the separation section directs only the scattered electron beam from the target into the electron multiplier. This improves the performance of the camera and it can operate at extremely low light levels.

4.5 Silicon Intensifier Target (SIT) Tube

In this tube, an intensified beam of electrons from the photoemitter falls on a silicon diode target. The silicon diode tube is a reverse biased junction consisting of an array of hundreds of thousands of diodes on a silicon wafer.

Each high energy electron can free thousands of electron carriers in the silicon wafer. Thus, SIT tube is a vidicon with an intensified target. This high modification allows the camera to operate at light levels much below that of the dark-adapted eye and finds applications in industrial and scientific fields too besides military use.

4.6 Charge Coupled Device (CCD) Imager

This is a solid-state device in which get the optical image is projected onto a large-scale integrated circuit device which detects the light image and develops a television picture signal. The term CCD refers to the action of the tube which detects, stores and then reads out an accumulated electrical charge representing the light on each portion of the image. A CCD imager can incorporate in an image intensifier tube and this highly sensitive set-up
can operate at very low light levels.

4.7 Infrared Solid 5tate Imaging Sensors (IRSSIS)

The A one -or , two-dimensional array of infrared sensitive elements forms a charge pattern representative of the heat distribution across the scene. This charge pattern is then read out via solid state registers and displayed to produce an image of the scene. One of the problems with these devices is the choice of detector material. A thermal imager of even moderate spatial resolution, if applied as a staring array imager, requires a large number of elements. The requisite processing precision is produced at a low cost in silicon based technology. Even if a practical solution to the cooling problem of extrinsic silicon detectors is found, there are many other problems such as detector uniformity, cross-talk and dynamic range which will require years of research and development effort to solve. The same holds true for a preferred direction of research at present, i.e. the mechanical and electrical combination of photovoltaic CMT sensors with silicon read-out arrays-a hybrid technology.

Currently available night vision systems are in two categories: light photoemissive detectors and thermal imagers, although both the systems have disadvantages and some of the detectors which are now in the R&D phase may lead to improved future night vision systems. Low light systems are relatively cheap, compact and have excellent performance over a modest range, but are adversely affected by haze and cloud. Scanned thermal imagers are expensive, require cooling but have access to a much higher photon flux at a waveband which is less affected by haze and smoke. The thermal imaging equipment which operates on an entirely passive basis is expected to gain general acceptance in the future. In the years to come, improvements would have to be made in the sensitivity of detectors and standardization would have to be extended, thus leading to a reduction in costs.

So long as war is at a probable, if one side were equipped with scientists and the other not, the scientific side would almost certainly win.

Bertrand Russell

Many ideas grow better when planted into another mind than in the one where they spring up.

Oliver Wendell Holmes

Ignorance of the law, it is said, is no excuse. In the twentieth century, ignorance of science should be no excuse.

R. Calder

When you meet with a difficulty, you are on the verge of a discovery.

Lord Kelvin

Imagination is more important than knowledge.

Einstein

5. NON THERMAL NIGHT VISION

The objective lens of a non-thermal night vision system collects available visible and near-infrared radiation from a scene, focussing it upon the input photocathode layer of an image intensifier tube which is the key component of such a system. An image intensifier reproduces the optical image of the scene on its output luminescent screen with increased brightness. This output image (usually coloured green because the human eye is most sensitive to green light) is viewed through a magnifying eyepiece lens by the user. Turning to the operation of the image intensifier itself, the photocathode layer, which is formed upon the inside surface of the input window of the image intensifier tube, liberates photo electrons into the tube's internal vacuum space in proportion to the amount of radiation falling upon it. The resulting beam of electrons, which is modulated in space and time by the input image information, is accelerated and focussed upon a final cathode luminescent screen deposited on the inside surface of the output window of the image intensifier tube. Such a screen generates light in proportion to the electron current density incident upon it, thus recreating the input optical image at the output of the tube. Acceleration and focussing of the electron beam are effected by electric fields created within the tube by the application of high potentials from the tube power supply to suitably shaped electrodes. Thus electrical energy, derived from the power supply, is imparted to the photo electrons, enabling each one to generate large numbers of photons of visible light in the luminescent (phosphor) screen.

The combination of tube technologies, viz., photocathode material, electron beam multiplication technique and method employed to focus the electron beam distinguishes image intensifier tube "generations", i.e. 1st, 2nd and 3rd. The English Electric Valve (EEV) Company, UK is currently manufacturing the 1st and 2nd generation intensifiers and will be manufacturing the 3rd generation in the near future.

First generation image intensifiers employ conventional photocathodes (i.e. Polycrystalline evaporated layers of positive electron affinity materials) generally combined with an inverting electrostatic lens to focus the electron beam onto the phosphor screen. With no internal electron beam current multiplication, greater gain is achieved by fibre-optically coupling these tubes to form multi-stage imaging assemblies, in which the image brightness is successively amplified by each stage. The complete assembly of coupled intensifier stages and their power supplies is referred to as a "cascade image intensifier tube". The most widely used are three-stage cascade image intensifier tubes with image diameters of 18, 25 or 40 mm. Such tubes have luminance gains of over 50,000 suitable for operation down to starlight levels of scene illumination.
Second generation image intensifiers also employ conventional photocathodes, but incorporate a micro-channel plate (MCP) to provide internal electron beam current multiplication, and hence extra gain, via the mechanism of secondary electron multiplication. When a primary electron with sufficient energy strikes a suitable surface, e.g. a partially-reduced lead oxide glass, it can generate an average of more than one secondary electrons which are emitted into the vacuum. This phenomenon is exploited in

the MCP electron multiplier, in which a multiplicity of parallel glass tubes forming a plate structure provide separate secondary electron multiplying channels for the electron beamlets corresponding to each element of the image. There are two types of second generation image intensifier tubes. The first comprises a first generation single-stage tube with inverting electron lens modified to focus the electron beam onto the input face of the MCP. The multiplied , electron' beam emerging from the output face of the MCP is then directly accelerated by an intense uniform electric field established across a very narrow vacuum gap onto the output luminescent screen. This arrangement is referred to as "proximity focussing". The MCP can provide electron beam multiplication factors of upto 1000 (yielding corresponding tube gains of 10,000 to 50,000) and can also provide localised limitation of image highlights or blooming control, a very useful feature in urban environments. The first type of tube described above is referred to as a crossover focussed second generation image intensifier. Such tubes are available in various formats, e.g. with equal input and output image diameters of 18 or 25 mm and also magnifying or demagnifying types with input/output image diameter combinations such as 20/30 or 50/40 mm. The second type of image intensifier tube employs the "proximity focussing" technique. twice between both the photo-cathode and MCP and the phosphor screen. This can be achieved only by special high vacuum, tube processing and construction methods referred to as "vacuum transfer technology". The tube processed by this technology is very compact and because of its internal arrangement is called "wafer tube". The wafer tube produces a completely distortion-free image with no change in the image size, i.e. unity magnification. The output image can be erect or inverted using a "fibre optic twister" as an output window. The twister rotates the image through 180° within a very short axial length with little loss of light. Wafer tubes, being compact and lightweight, are available with image diameters of 18 mm. They are suitable for headmounted night vision goggles. Gains are typically 10,000 and the small size is achieved at the expense of image definition.

Third generation image intensifiers are becoming available in the form of wafer tubes with almost identical outlines to the second generation wafer tubes but incorporating a new single-crystal photocathode made of gallium arsenide. The gallium arsenide vacuum surface is treated with caesium and oxygen in order to achieve a negative electron affinity" (NEA). Photo electrons produced by absorption of light within the gallium arsenide, which reach the vacuum surface, escape from NEA surface. In a conventional photocathode, many photo electrons 'fail to escape into the vacuum, thus reducing its efficiency. There are some minor differences in tube construction and major differences in tube processing technology but both second and third generation image Intensifiers are suitable for small lightweight night vision systems. However, the third generation image intensifiers will provide improved performance in suitably designed systems on account of much higher sensitivity available from gallium arsenide photocathodes.

6. APPLICATIONS OF NIGHT VISION TECHNOLOGY

If a narrow field of view is specified, for example in weapon sights or missile aiming and guidance systems, then the choice generally lies between image intensifiers and CMT thermal imagers.

6.1 NARROW FIELD OF VIEW

6.1.1 Infantry Weapon Sights (IWS)

Here the need for portability outweighs almost all other considerations; so today image intensifiers are the obvious choice. Although cascade tubes were used originally, the latest designs use MCP tubes. The choice of tube depends on several factors; range, flash protection, ability to operate in urban environments, weight and, of course, cost. With these considerations in mind, the following second generation tubes are recommended.

Good performance, low weight, low cost - X1500.
Good performance, very low weight, small size, low cost - X 1410.
Superior performance, low weight, moderate cost - X1380.

6.1.2 Gunner Sights

Armoured vehicles (tanks, etc) and medium range guns need night sights with a range of 2 to 4 km. Formerly, 25 mm or 40 mm three-stage cascade tubes were used for this purpose and more recently, MCP tubes such as the XX1380 are being used. However, loss of contrast caused by atmospheric scattering in adverse weather conditions can be overcome only with thermal imaging systems incorporating detectors such as M 2 RPY or M3 RPY. These systems are, at present, much more expensive than image intensifier systems and will remain so for a considerable time.

6.1.3 Naval Trackers

These systems are intended for spotting missiles and aircraft (including sea-skimming) on the horizon. They usually employ CMT infrared detectors, such as the M3 RPY. Sometimes these systems are wrongly called thermal radars.

6.1.4 Remotely Piloted Vehicles (RPVs)

Infrared detectors are recommended for RPVs and for some guided missiles that are self-directing, since they provide a ready means of finding position relative to a hot body. The candidates are the M1 and M2 RPY CMT detectors.

6.1.5 Anti-tank Missile Guidance

Anti-tank missile guidance systems such as Milan use thermal imaging sights to facilitate missile guidance. Infrared detectors such as the M2 RPY are ideal for this application.

6.1.6 Hand-hold Observation Sights

These sights usually use image intensifiers such as the XX1380 or XX1500. However, as their price drops, CMT thermal imagers using thermo-electrically cooled detectors such as M1 RPY should become more important. At present thermal imagers are used only in rather special applications.

6.1.7 Commander Sights

Most modern tanks are fitted with three optical systems: driving, aiming , and commander sights. There is no clear preference in commander sights at present, different systems meeting different needs. Some armies use narrow field of view systems similar to image intensifier gunner sights; others prefer wide field of view systems similar
to driving sights. In the future, demands for commander sights with increased range are likely to cause a switch to
thermal imagers.

6.2 WIDE FIELD OF VIEW

6.2.1 Driving Sights

First generation XXl080 night driving tube is a highly successful tube and is most widely used. The tube, which incorporates electronic protection against highlight damage, suffers far less from blooming than first generation cascade tubes.

Second generation 50/40 XX1332 image intensifier-50 mm photocathode 40 mm screen is an ideal size relation, allowing the user to employ wide, aperture, wide field of view objective lenses with low magnification binocular eyepieces. Compared with the US25/25 mm tube with fibre-optic expander, the XX1332 offers a 4 times higher luminous efficiency and much higher resolution.

Recently, opinion has varied widely over the usefulness of thermal imagers as driving sights. However, since these devices offer no over-riding advantage over image intensifiers for this application and since usually a driver is interested only in avoiding obstacles, we do not expect the thermal imager to replace the image intensifier atleast within the near future.

A survey on driving sights would not be complete without goggles.

6.2.2 Goggles

For a general use there is only one realistic option-second generation proximity -focussed image intensifier Candidates include: the XX1390 and XX1410 -lightweight, proximity, focussed tubes with 18 mm input and output windows. The latter device incorporates a fibre optic twister (image inverter) as the output window and integral power supply (with automatic gain control). For aviator's goggles, the introduction of third generation tubes may take place in the years to come. But the improvement in their price-performance ratio has been slower than anticipated, which could restrict their use to special-purpose sights for many more years.

6.2.3 Pocket Viewers

The small hand-held devices, for use by patrol leaders and policemen in urban environments, should be able to operate upto a range of about 200 metres. Here again, second generation devices are favoured because of their low weight and compactness. We can recommend the XX14lO and for longer range, the XX1500.

6.2.4 Remote Surveillance

Although PEVs such as the 66XQ are suited to this application, an alternative solution would be the new XX1500 TV second generation image intensifier coupled to a Newvicon camera tube, depending on field requirements or circumstances.

In many applications of electro-optics night vision technology, the available natural illumination is insufficient to provide the desired resolution or image quality. In those cases, it is frequently desired to provide illumination that is covert and cannot be seen by the unaided human eye. As far as the practical approximation to the visibility of infrared sources is concerned, an estimate that is correct within a factor of two is quite an acceptable success considering the degree of knowledge and the probable scatter of human eye sensitivity.

In the development of military night vision system, the basic goal of conducting operations at night with near daylight efficiency has resulted in continued emphasis on such efforts as the development of image intensifier night vision goggles, better IR detectors and now the completion of a standard module FLIRS (Forward Looking Infra-red System).

There is no adequate defence except stupidity against the impact of a new idea.

P. W. Bridgeman

7. DEVELOPMENT ON NVDs IN

7.1 FOREIGN COUNTRIES

In this chapter, a detailed description is given of the present status of the versatile night vision technology. Accumulated combat experience and new research and development efforts in the field of night vision technology are reviewed. It is shown that current developments and testing have demonstrated an improved capability in night vision technology, using either selected specialists without night vision systems or a wider group of personnel on land, air or sea aided by the night vision devices. For all newer devices developed in foreign countries, various night vision laboratories have developed new methods of testing and criteria for specifications, that require considerably better correction than had previously been required. The principles and characteristics of these innovations are discussed and some of the important parameters, which can affect the performance of passive night vision systems, are highlighted. Factors pertinent to illumination, target characteristics, photocathodes, distortion, etc are considered. This chapter has the purpose of giving a comprehensive discussion on the important night vision devices developed by leading manufacturers in foreign countries.

7.2 Elcoma's Night Vision Components Group

The products of Elcoma's Night Vision Components Group are image intensifiers, thermal detectors, low-light TV tubes and other night vision, devices. Since it is part of Philips Elcoma, the Night Vision Components Group is independent of the parent company's Defence and Control Systems Division. Philips obtained its first patent on image-converter tubes as far back as 1928 and became actively involved in developing night vision components some two decades ago. The company claims to be the only one in the world to make image intensifiers completely
red in-house, including the glass, micro-channel pIates, fibre 'optics, phosphors,' and photocathode materials, semiconductor and other components used in power supplies. Philips Usfa's UA 1116 individual weapon night sight weighs only 1.4 kg and is claimed to be one of the smallest, lightest types available for use with portable weapons. The sight can be used with rifles, machine guns, grenade launchers and recoilless rifles. The UA 9630 driver's universal passive periscope established the reputation of Philips Usfa in the field of passive night vision and has been supplied throughout the world. The periscope has a field of view measuring 50° horizontally by 40° vertically, with X 0.9 magnification.


Philips Usfa's UA 1116 individual-weapon night sight

Elcoma (Electronic Components and Materials) has developed a range of image intensifiers, of both first generation (cascade) and second generation (microchannel pIate} types for a wide variety of applications. The XX1410- series 18 mm double proximity - focussed tubes are a direct replacement for the US Type MX99 I 6/UV in goggles and pocketscopes and are specified as standard by most defence authorities in the world for use in night Vision goggles. The XX1390 family of 18 mm double proximity focussed tubes have no fibre-optic inverter and are thus significantly lighter; the XX1390 is claimed to be the smallest and lightest (45 kg) tube in production anywhere in the world. The noise inherent in the picture produced by the microchannel plate could be suppressed by incorporating magnification in the design, with the output window larger than the input window. The result was the XX1380 series of (20 mm input window, 30 mm-output window) tubes which are claimed to be the highest performance second generation tubes in the world. The XX1380 provides a gain of upto 25,000 and provides more than 1000 line-pairs of information on its 30 mm-diameter output screen, yet is only 8 cm long and weighs a mere 350 g. When used in a rifle sight, the XX 1380 allows a man to be seen under near startlight conditions at a range of 950 m. Elcoma has also developed the XXl500 (18 mm) second generation tube that is smaller, lighter (185 g) and less expensive than the XX1380. The XXl500 can be used in rifle sights weighing about 1 kg in all, yet allowing a man to be seen at a distance of 800 m under near Starlight conditions. For driving and submarine periscopes, Elcoma has developed tubes with 50 mm input windows, so that large diameter objective lenses can be used to gather as much light as possible. The technology suitable for third generation tubes involves the use of gallium arsenide photocathodes. The company is carrying out research and development on other technologies that have potential application in night vision devices, including infrared imaging charge-coupled devices (CCDs) and pyroelectric vidicons, and has made a large investment in thermal imaging detectors. Elcoma grows its own crystals of cadmium mercury telluride (CMT) and offers a broad range of infrared detectors in standard or customised configurations.

7.3 Oldelft Passive Minisight

Oldelft, the full name of which is NV Optische Industrie de Oude Delft, was founded in 1939 and has since developed a wide range of military products. Oldelft started work on near IR devices in 1965. Oldelft is working on devices incorporating third generation tubes, which the company expects would become available over the next five years. The company intends to continue its image-intensification business alongside developments in thermal imaging. Oldelft sees thermal imagers gradually becoming the norm for heavy weapons and vehicles, with image intensifiers continuing to find applications in smaller weapons and for patrol work.

Oldelft started development work on lasers in 1963, originally with ruby lasers and later with the neodymium type. The company is producing its Mini-Laser rangefinder for use with artillery and mortars.

Oldelft Passive Minisight is designed to match present and future generations of light and small automatic rifles and light machine gun. It is an ultra range lightweight, second generation night or aiming device complete with all the essentials that make it stand out against other small instruments in this category: lightweight, super sturdy in heavy field use, easy to handle, excellent range of vision, etc. It can also be used as an observation device and as an infrared detection system. In brief, the only thing that is "mini" about this new weapon sight is its size and weight.

7.4 Eltro Optronic Devices

Eltro, a well-known company specializing in the fields of night viewing, thermal imaging and laser technology, presented its newest products at the ENSEC 83 in Brussels recently. These included eye - safe lasers, e.g.

7.5 CO2 lasers which operate in the 10.6 m wavelength range.

Lasers containing RAMAN cells able to shift the wavelength such that the emitted laser beam lies in an eye -safe wavelength range.

The mini-laser rangefinder for infantry use, a semi conductor laser offering low-power transmission and a special measuring method.

These lasers have been developed by Eltro and are available as samples for testing purposes. Laser rangefinders operate in the near IR range applying the time delay method. The energy emitted by the laser beam transmitted is reflected by the target. The receiver which is integrated with the transmitter in one unit receives the reflected energy. The data processing electronics record the time delay and convert it to range parameters. The range data can be mirrored into the observation field of a sight or displayed directly on an indicator. Other fields of application are lasers for target illumination, target designation and information transfer.

7.6 Simrad Optronics

Simrad KN 150 is suitable for general surveillance, battlefield night observation, and police and security forces. It is a hand-held passive night observation sight which combines high performance with simple operation. Tank-sized targets can be detected easily at 1500 m. Binocular eyepieces minimize operator fatigue compared with monocular viewing and make it possible to maintain continuous surveillance for long periods. To ease handling, only two controls are fitted: an "ON" switch and a twist-grip focussing arrangement. Focussing range is from 25 m to infinity. Automatic brightness control reduces the amplification of sudden bright lights, thus preventing the operator's eyes from losing their night adaptation. Normal operation is restored less than 1 second after a sudden flash from an explosion or from vehicle lights. The KN 150 incorporates a large aperture catadioptric objective lens and a second generation, high resolution microchannel image intensifier tube. Two standard 1.5 V dry cells provide more than 40 hours observation. The weight is only 2.5kg. The KN 150 can be combined with a SIMRAD laser rangefinder for night time observation and localization of targets. Other products manufactured by Simrad Optronics are: (i) Laser range finders for use by artillery, infantry and mechanized troops, as well as for air defence, air force and navy; (ii) Laser threat warning receivers; and (iii) IR thermal imagers for navy and coastal artillery.

Simrad Optronics A/S of Oslo, Norway, one of the leading manufacturers of sophisticated electro-optical equipment in Europe, announced that the Norwegian and Swedish Material Commands have jointly placed orders for a substantial number of their hand-held laser rangefinder LP 7 at a total value of $ll million. Deliveries will take place over the years 1984-1988. This is the second largest order for the LP 7 placed by the Norwegian Army, whereas the Swedish Army is now equipping their troops with hand-held laser range-finder for the first time. Hopefully, the other branches of the Norwegian and the Swedish Defence Forces will appreciate the usefulness of hand-held laser rangefinders in many other roles and exercise the options in the contracts for additional procurements. The rangefinder was used with great success by the British troops during the Falkland comparing. Recently the British Army decided to place their third order for the same equipment.

The completely self-contained battery-powered laser range finder with the shape and size of a 7 x 50 binocular weighs only 2 kg and can instantly measure ranges to targets 10,000 m away with an accuracy of 5 m means of invisible laser beams.

7.7 New Night Observation Device

A hand-held passive night observation device which combines high performance with simple operation has been developed jointly by Bofors Aeronautics, Sweden and Simrad Optronics, Norway. This device can be used like binoculars. The instrument incorporates a large aperture (f-stop 1.3) catadioptric objective lens and a second generation, high-resolution microchannel image-intensifier tube. The focussing range of this device is from 25 metres to infinity. Tank-sized targets can be observed at 1500 metres. To minimize training requirements, only two controls are included: an 'on' switch and a focussing adjustment.' Binocular eye-pieces were used after tests demonstrated that monocular viewers caused greater eye fatigue. Using both eyes, it is possible to maintain continuous surveillance for long periods. Two standard 1.5 volt dry cells power the device for upto 40 hours. An automatic brightness-gain control is incorporated into the device to reduce the amplification of bright lights, thereby saving the operator from being temporarily startled. Normal operation is restored in less than one second after a sudden flash from an explosion or from vehicle lights.

7.8 Cyclops Night Vision Goggles

Cyclops Night Vision Goggles are based on a single.

Second generation image intensifier tube with lightweight housing and high speed optics. They are quick to put on and comfortable to wear even in a helmet. The wearer can work efficiently with no illumination and with both hands free, capable of performing a variety of tasks at night such as driving, patrols, first aid, map reading, repairs, loading and unloading, flying helicopters and low speed, fixed wing aircraft or working in bunkers and tunnels.

7.9 Cat's Eyes Night Vision Goggles

Marconi Avionics Airborne Display Division has combined its expertise in head-up displays, and image intensification to produce the Cat's Eyes night vision system for helicopter pilots, missile operators, infantry, naval personnel and other operators who require a wide field of view at night. It can be attached to the front of most types of flying or protective helmets. Light from the outside scene passes through a pair of conventional image intensifier tubes; the intensified image is then projected onto a plasticecombiner in front of the operator's eyes, giving a clear image scaled I: 1 with the outside world and superimposed on it. The result is a clear, bright, binocular image -with symbology overlaid on it if required -which permits full night operation but does not obscure direct vision. The electro-optical field of view measures 450 in azimuth by 300 in elevation and the operator has interrupted peripheral vision around the edges of the combiner. It weighs 0.86 kg and is claimed to have a lower moment about the helmet than conventional night vision goggles.

7.10 Infrared Aiming Light

The Infrared Aiming' Light (IAL) was developed for use by Ranger battalions (TOE 7-85 H). It is a battery-powered device, which projects a spot of infrared light that can be seen at night through the standard night vision goggles (NVG). The IAI: weighs 11 ounces and can be mounted on the MI6AI rifle, the M60 machinegun, the LAW and .
the 90 mm recoilless rifle.

The Infantry Board at Fort Benning IAI conducted first part of the operational test using soldiers from the 197th Infantry Brigade as test personnel. The last part of the test consisted of ranger exercises conducted by the lst Ranger Battalion at Fort Stewart, Georgia. The test soldiers were trained by Infantry School personnel in the use of the night vision goggles and the aiming light during the Fort Benning Phase. The test soldiers then participated in timed exercises that included mounting and zeroing or boresighting the IAL on the rifle, machinegun, LAW recoilless rifle. They fired at a series of E-type silhouette targets at ranges upto 200 metres at night, firing both the rifle and the machinegun, and fired the rifle on the Board is instrumented quick fire facility. During this firing, which was conducted for comparison purposes, the test soldiers used the NVG/IAL combination, the NVG alone and also conducted limited firing using the individual night vision sight, AN/PVS-4. Limited firing was conducted during the day with the rifle and the machine-gun. Standard iron sights were used with the IAL, because the infrared spot of light cannot be seen during daylight, with or without the NVG. The IAL was also subjected to 48 parachute jumps at Fort Benning.

7.11 Trilux Infantry Night Sight

A very compact and lightweight sight has been designed by the Royal Armaments Research and Development Establishment (RARDE), UK to enable the infantrymen to fight more effectively at night and also to identify and engage ill-defined targets at greater ranges by day. It is suitable for fitting on all rifles and LMGs and has been a successfully evaluated under operational conditions by the British Army in Northern Ireland. The sight can be quickly removed from the weapon and after refitting does not need to be readjusted before firing. Instead of a cross-hair, an aiming pointer is fitted in the upper half of the optics which provides X4 the magnification. The pointer is illuminated by a red trithium (Trilux) power source requiring no external power supply, the intensity of which is infinitely invariably by means of a control lever on top of the sight body. A two-position range control lever on the right-hand side of the sight has settings for ranges of upto 400 m and 400-600 m respectively. Zeroing can be performed using screw driver or a small coin. Technical characteristics of the Trilux sight are as follows: Length -18.8 cm; Width-7.6 cm; Height -6.9 cm; weight -340g; Magnification -X4; Objective Aperture (clear) -25.5 mm; Field of view -8°(140 mils); Light Transmission greater than 80%; Exit Pupil Diameter -6.6mm; Eye Relief -35 mm; Field Distortion negligible; Veiling Glare 2% max; Graticule illumination red trithium light source (variable); Environmental conditions -completely sealed, operation and storage between -75 and +90 C.

Mountings for fitting to 7.62 mm FN rifle; 7.62 mm FN GPMG; 5.56mm M 16 rifle; 84 mm Carl Gustaf antitank weapon; 7.62 mm G3 rifle have been provided. Aviator's Night Vision Imaging System (Anvis-Hughes Optical Product) Developed by Hughes Optical Products for the US Army Night Vision and Electro-Optics Laboratory, ANVIS is a helmet-mounted, image intensified binocular permitting covert, night time, nap-of-the-earth and contour flight, are in either fixed wing aircraft or helicopters. It can be used to conjunction with FLIR systems to optimize 24 hour/ adverse weather operational capability.This is the only 12 goggle designed specifically for pilots and is fast becoming the world's standard night vision system for piloting aircraft on account of its exceptional reliability. It is simple and lightweight design with unobstructed "look-around" peripheral vision. This system is easy to install and comfortable to use, thus assuring optimum aircraft safety. It costs a small fraction of thermal imaging piloting systems. There is provision for second generation/third generation tube interchangeability also.One can buy hot second generation tube now and field retrofit to third generation later .

7.12 Aviator's Night Vision Imaging System (ANVIS-Bell & Howell)

A new Night Vision imaging system has been developed by Bell and Howell to meet a military requirement for an aid to nap-of-the-earth flight at night and in low-light-level conditions.The imaging system consists of a binocular assembly, second or third generation image-intensifier tubes, a helmet visor mount and a battery power pack. Upgrading of a second generation system to the third generation system is carried out simply by changing the image-intensifier tubes. The binoculars give a field of vision of 40 degrees and have a focus range of between 25 centimetres and infinity. To aid correct fitting, there is 16 mm of travel available for eye relief and vertical adjustment,and the distance between the pupils can be adjusted between 52 mm and 72 mm. The unity vision binoculars weigh 462 g, although the total system's weight depends on the type of helmet mount used. The binoculars require a 2.9 V d.c. power supply, which can be provided either by the batteries, or direct from the aircraft's power supply via an optional aircraft power converter.

7.13 Hughes Helmet Night Vision for Pilots

A Hughes Aircraft Company test pilot is shown wearing a helmet with a head-up visor display, which is part of a new helicopter night vision system developed to improve a pilot's vision on low level missions at night in adverse weather or in hazy and smoky conditions. In flight, a forward -looking infrared (FLIR) image, which resembles a black and white TV picture, is projected onto the helmet visor so that the pilot may see the world outside his cockpit. His head movements are instantly transmitted through servo linkage to the FLIR turret (under the helicopter) which is automatically aimed along his line of sight. Hughes is currently demonstrating its system on the company's Bell 206 L helicopter .

7.14 Night Viewing Device (Model 223)

A passive night viewing device (NVD), Model 223, for military use has been developed by Apollo Laser Inc., USA. The device is heavy duty, ruggedized, waterproof and permits seeing in darkness using a highly sensitive image intensifier. The Model 223 is equipped to hold up against extreme shock and vibration. It can be rifle mounted with adjustable windage and elevation. It can also be used with photographic and television equipment. The device incorporates an exclusive battery test indicator with an automatic brightness control, a secure type eye-guard, which allows no light to be reflected on the operator and optionally a focal plane-field iris.

7.15 Night Observation Devices (Model 229)

A new night observation device (model 229) , a waterproof, militarized and ruggedized instrument used for direct observation and target acquisition, has been developed by Apollo Lasers Inc., USA and is being currently used by the US Army. The device is shock resistant and is designed to meet all military specifications. The coordinates (azimuth and elevation scales) are built into the unit and can pinpoint targets ranges in excess of 1000 m after they have been located and identified. The unit can be easily varied in azimuth and elevation to search the entire field of view or the horizon. It has a self-contained tripod that extends approximately 30 cm above the ground. The image intensifier tube of this night observation device amplifies incident light approximately 100,00 times. It does not emit any form of energy and thus cannot be detected. The lens is sealed and purged with nitrogen to prevent fogging caused by condensation. It is powered by a self-contained battery and comes in a fully militarised case.

7.16 Pilkington Eagle Night Sight

A new hand-held surveillance sight Eagle, weighing only 2.5 kg, and which provides a night range capability comparable with earlier mounted systems weighing upto 20 kg, has been developed by Pilkington, P.E. The sight gives X8 magnification, employs a lightweight catadioptric lens and a single second-generation image intensifier tube. Range used performance with the second generation image intensifier tube is the recognition of a main battle tank at 1000 metres under clear starlight conditions. With third generation tubes the recognition is extended to 1400 metres. The binocular eyepiece, already well-proven in the company's Nova night vision goggles, gives generous eye adjustment and enables the night scene to be viewed with both eyes simultaneously. The eyepiece is compatible with a variety of helmets, military respirators and nuclear biological and chemical (NBC) clothing and equipment.

Power is supplied from 2 x 1.5 volt AA size batteries, commercially available and providing upto 40 hours' continual operation. Eagle is simple to operate and easy to handle with controls being restricted to an On/Off switch, and focus and graticule control illumination. The sight can be mounted on a lightweight, low level tripod fitted with an azimuth head. Vernier scales give precise elevation and bearing information to aid mortar and artillery fire control. An adaptor to raise the azimuth head by 250 mm is also available.

7.17 FLIR Systems from Detection to Recognition in a Split Second: An Innovation in Thermal Imaging

A FLIR-equipped helicopter has the tactical advantages: at night, against camouflage, in smoke, through dust and haze. A FLIR-equipped helicopter has also the strategic advantages: Reconnaissance, Target Acquisition, Surveillance, Pilot Night Vision, Border Patrol and gain the edge with the Model 2000A Thermal Imaging System designed for helicopters. The system is totally operated from the cockpit. A hand-held controller puts all system functions within easy reach. High-resolution infrared imagery is displayed on a TV monitor. A wide-angle lens sweeps large areas for target detection. With a switch, flip to a 4X telephoto mode in a split second for target recognition. The model 2000A is a high-performance thermal sensor cradled in an aerodynamic Precision Pointing System (PPS) allowing flight speeds to 180 knots. A "quick-mount" feature enables the entire system to be installed or removed in minutes. The compact and lightweight configuration makes the Model 2000A suitable for use on most helicopters. The simplified modular design provides rugged reliability, ease of maintenance and minimal downtime.

7.18 Baird Night Vision Technology

One of the great names in night vision technology is Baird. The Bedford-based company offers a broad range of night vision systems for a variety of applications. The' NDS - 2 Night Viewer is a second generation equipment for fixed installation in armoured fighting vehicles and battle tank as a driver's viewing aid. The equipment is available in various configurations for individual user specifications. Night vision goggles with binocular eyepiece set and single lens viewer for various magnification factors are supplied for artillery gunners, helicopter pilots and as observation aids. The image intensifier is a second generation MCP type with !8 mm lens. Special equipment for firing is Nightfighter aiming telescope. The Nightfighter can be used on rifles, handguns and submachine guns either as a normal night vision aiming telescope or strapped to a head-set in combination with a laser spot on the weapon for firing in total darkness.

7.19 Sopelem Systems

Sopelem, specialist in optronics and computer systems, has applied its technical expertise to developing day/night sighting systems. Besides a wide range of individual and tank equipments, Sopelem is now offering a large programme of services, starting with the conception of specific systems to the training of maintenance personnel. With their high performance and reliability, Sopelem equipments fit at the French Army specifications.

7.20 Lasergage Devices

Lasergage Ltd. now manufacture a complete range of second generation night vision equipment. By using the same eyepiece, battery and image intensifier tube, easy exchange of modules can take place between the PVS4, TVS5, and NOD2. The PVS4 is a light weight unit for use by infantry and is easily adapted to a number of different weapons. The TVS5 Crew-Served Weapon Sight can be attached to various heavy or medium machine guns and is ideal for use with anti-tank guns such as the M106. The Lasergage Night Observation Device (NOD2) is tripod mounted and it can be used by Forward Observation Officers, Reconnaissance Parties and Naval Units. The LP hand-held Laser Rangefinder can be mounted on this unit with a special bracket for alignment, producing a very effective fire control system for night use. The PVS5A Night Vision Goggles are designed for use by helicopter pilots, drivers, maintenance teams or any personnel who need to work in black-out conditions. They also enable the infantry or groups to patrol at night and to locate the enemy. An infrared facility also enables them to read maps with a range of 10" to infinity. The Night Vision equipment manufactured by Lasergage Ltd. is built to the accepted and proven design to US Military Standards. This equipment is in service with the US Armed Forces and many other forces worldwide.

7.21 MIRA Night Sight

MIRA Night Sight (TRT , France) basically consists of a Germanium Objective Glass, Opto-mechanical scanning unit, a MCT detector and LED display unit. The OG is a 100 mm diameter f/2 system having a transmission of over 85% in 8-13 f m region. Scanning is done by an oscillating mirror (for vertical scanning) and a rotating polygon having six faces (for horizontal scanning). The MCT detector consists of 30 elements arranged in 6 rows (5 in each row). The detector is cooled using Joule-Thomson principle with the help of a gas bottle of 0.33 litre capacity filled with nitrogen under pressure, having an operating duration of 2 hours. The image formed on the detector is displayed on LEDs operating at 0.65 m and arranged in an identical manner as the detector itself is projected into the eyepiece of the localiser unit. The horizontal and vertical FOV of the sight is 60 and 30 respectively and the minimum resolvable temperature difference is 0.160C. Observations made through the sight indicated that tank targets were clearly seen upto a range of 1500 metres.

7.22 Philips Night Vision Components

Philips night vision components are at the heart of sights, goggles, driving periscopes and guidance and surveillance systems all over the world. All have one thing in common: the need for uncompromising standards of performance and dependability even under the toughest operating conditions. Philips Night Vision Components have comprehensive range, total in-house capability, participation in major defence projects such as MILAN and a unique combination of advanced technology and guaranteed quality.

7.23 Wild BIG 2 Optical Instruments

Wild BIG 2 is the lightweight, safe, invisible amongst night vision goggles with decisive advantages. In daytime they are not required but the bright light of day is the time to think about needing them at night. One may remember. in daylight that at night only night vision goggles tested to MIL standards and with extra features will be good enough. They have what various other night vision goggles also have. But they have a few things more: they
are more comfortable than others, to keep the wearer of Wild night vision goggles fitter longer. And they have an LED infrared light source that you can switch on for additional illumination, so that you and your men can see more at night. And they have high-quality Wild optics to provide the sharpest image. Wild BIG 2 thus forms part of the world's leading range of modern precision-engineered optical and electronic instruments made by a very large company.

7.24 Night Vision Aid (AN/NS-7(XE-l)

A low-cost night vision aid designated   AN/PVS-7 (XE-l) has been developed by Bell and Howell, USA. This device has a third generation image intensifier tube and lightweight plastic optics and mechanical parts. Its design is based on 'cyclops' concept whereby both eyes view through the same image intensification tube. This is in contrast to the night vision goggles, such as AN/PVS-5, which have two image intensification tubes and optical systems, each for one eye. As the tube is the most expensive component, the cost of the new aid is significantly less than that of AN/PVS-5, while having comparable performance.

7.25 New Infrared Devices (T -2 Thermograph)

New applications of infrared announced by the Army include a jeep-mounted thermograph which senses the infrared thermals emitted from personnel, vehicles or terrain and records the true outline of the object on polaroid film. Designated the T-2, the thermograph will negate the concealment normally afforded to the enemy by darkness. The device is sufficiently sensitive to record body heat given off by personnel and solar heat absorbed by material during the day, which is given off during the hours of darkness. Other infrared devices include searchlights, periscopes and binoculars which will enable tank operators to observe the enemy at using either visible or infrared light. Such items are included in a tank kit developed by the US Army Engineer Research and Development Laboratories at Fort Belvoir, Virginia. The kit includes a Xenon searchlight which operates in coordination with the tank's gun. The beam of the search-light can be varied in width and intensity in either light mode. A compatible gunner's periscope has both wide-angle and high magnification channels using ordinary light and a high-magnification channel using infrared. A tank commander's periscope will provide him with a closed hatch infrared viewing capability. Open hatch viewing will be afforded by the use of a hand-held infrared binocular .

7.26 EEV Image Intensifiers

Night vision performance is all about the Image Intensifier-that's the tube at the heart of your night sight. The question is, can you always rely on it? Especially in the toughest battle-field conditions when the difference between seeing and not seeing is a matter of life or death? With EEV Image Intensifiers, one need have no doubts, for they have proved their mettle under very tough battlefield conditions indeed! EEV intensifiers ensure consistent target picture quality over the widest temperature range. They are also flash protected, taking less than a second to recover, unlike many intensifiers that leave one in the dark for more than four critical seconds.

What is more, EEV is offering three different generations of intensifiers. There is first generation that extends sights upto 2000 metres--a clear 400 metres ahead of other systems. There is second generation that withstands hand-held weapon shock loadings like no other 18 mm intensifier can do. And now, we have third generation. Whatever may be night-vision needs long or short range, crew-assisted or hand held -one can be sure of an EEV intensifier just made for the job.

7.27 EEV Image Intensifiers in both 25mm and 18 mm types provide:

(i) Improved range performance.
(ii) Flash protection against battle-field conditions.

(iii) Constant performance over a wide temperature range.
(iv) Constant performance even with reduced battery voltage.
(v) Fast recovery time (less than one second) when exposed to highlight.
(vi) Overload (standard intensifiers take more than 4 seconds to recover).

7.28 Star- Tron Night Vision Equipment

Smith & Wesson offers one of the most rugged versatile and proven lines of passive night vision systems.

7.29 Versatility

The unique interchangeability of objective lenses, oculars and other components enables the Star-tron Mk 303A to meet multiple military requirements for patrol duty, long range surveillance, photography and weapon applications. Five waterproof, shock resistant lenses are available: 135 mm, f/l.6; 170 mm, f/l.5; 300 mm, f/l.8; 4l0mm, f/l.5 and 600 mm, f/l.7. Three binocular and four monocular viewers and relay lenses for still, motion picture and television photography are also available.

7.30 Unmatched Performance

The Star-tron Mk 303A, with intensifier tubes providing high resolution and gain, provides the clearest and brightest image available. Smith &: Wesson makes its own lenses from the individual elements to the finished lens. Lens transmittance, contrast and resolution characteristics are exactly matched to the requirements of the intensifier tubes to obtain the highest level of performance.

7.31 Universal Rifle Mount

Adaptable to all modern military rifles, this unique mount provides day-light and night scope interchangeability, is adjustable for elevation and windage, features repeatable bore sight, illuminated reticle projector and forward and back adjustment. Total weight of the Star-tron Mk 303A and mount is only 3.175 kg (7 lb).

7.32 Rugged Construction

Positively sealed for maximum protection, Star-tron units are waterproof, dustproof and shock resistant to survive the most demanding military environments. They incorporate the most advanced protective coating and have a deeply knurled body covering for safe handling and easy focussing. All electrical contacts are gold plated and all major circuitry encapsulated in silicone rubber for maximum electrical efficiency and resistance to corrosion.

7.33 Minimum Maintenance and Training

Star-tron night vision systems require virtually no maintenance other than an occasional cleaning of lenses. Minimum training is required because Star-tron equipment is simple and easy to operate.

7.34 Second Generation Systems

Incorporating micro-channel plate intensifiers, the second generation Star-tron Mk 323 is small and compact with minimal distortion and flare. Image quality, resolution and contrast are in the best available in second generation equipment. All Mk-303A objective lenses, oculars and accessories may be used with the Mk-323 thereby enhancing the versality of the basic Star-tron system.

7.35 Test Set -Type ETS47 A

It is neither easy nor necessary to remove military night sights from the vehicle on which they are needed in order to undertake a complete test of their efficiency.

The Test Set, Type ETS47 A, enables a complete check of the night sight, its power supply and the image tube to be undertaken in situ .

Photometric and radiant energy measurements normally made under dark room conditions are achievable in full day light.

The test set is contained within two transit cases weighing only 24kg, complete with its own rechargeable battery supply and a full range of adaptors, which enable a wide variety of sights and tubes to be tested by this equipment.

7.36 Rank Nightsights

Rank can now equip an entire army in the field with nightsights: Field commanders, Infantry men, Field commanders, AF gunners, Observers and recce personnel. With Rank nightsights many parts are interchangeable. 'Rank nightsights out-perform any other night vision equipment. For Instance, the latest AFV sight combines a day and night facility in one unit. Rank nightsights are the most superior ones; they are tested and proven in action in major wars and guerilla warfare throughout the world and they have a long operational life - at least 10 years.

7.37 MEL Night Periscopes

To assist armoured vehicle commanders in driving and sighting their vehicles at night, MEL have developed a range of night-viewing periscopes. MEL night periscopes are designed to fit most types of current armoured vehicles and are produced for the British and several overseas armies.

Night Vision Systems are part of MEL's continuing involvement in defence systems in the air, on the ground and at sea. These include Vehicle Radios; Naval Communication Systems; Portable Approach Guidance; Equipment for Aircraft; Avionic Systems; Electronic Warfare Equipment; etc;.

7.38 Night Observation Binoculars

A passive binocular employing light intensification system has been developed by TRT, France. The binocular comprises two objectives and two eye lenses. It uses microchannel tube with double proximity focalisation. The binoculars are designed for the observation of targets by night and can recognize a tank at a distance of 500 m with a luminosity of 1 millilux. The passive binocular has two separate vision paths, each consisting of a microchannel light intensifier tube, thus ensuring comfortable stereoscopic vision. The two body elements of the binocular are identical and completely interchangeable. The adjustment of the interpupillary spacing of the binocular is carried out by rotation of the body elements. The primary power is supplied from a small battery . The binocular weighs 1.85 kg. Its small bulk enables its utilization in the turret of a tank and it can also be mounted on a tripod. It has a magnification of 4X, a field of 8° and the focussing is continuous from 20 metres to infinity.

7.39 Night Sight for Semi-automatic Rifle

The passive night sight that permits observation in the dark, using the illumination of the night sky only, has been developed in France. The sight lens projects the very weak sky light reflected by observed objects onto a photo-cathode tube which intensifies the image. The power needed to activate the intensification tube is provided by a transistorized oscillator producing an alternating current, allied with a voltage multiplier.The tube intensifies the light generally by at least 40,000 lumens. The equipment is in the form of a self-contained high voltage powered telescope of magnification X4, with power produced by a 6/7 volt battery and a high-voltage generator. The telescope includes screw fittings for mounting on the weapon. The sight has an elevation and bearing reticle adjustable to ± 30 miles and the equipment is proofed against climatic variations, water saline atmosphere, shocks and vibration. Its characteristics are: Field, 8º; Focal length, adjustable from 10 metres to infinity; Battery life; 25 hours; and
Temperature range 20º to +40º C.

7.40 Helicopter Night Vision Aid

A new stabilised night vision system which can give a helicopter pilot virtually all-round vision at night has been produced by Marconi Avionics, UK. The system is mounted beneath the nose of a helicopter. It comprises a highly stabilised platform bearing a night vision sensor. The platform has been designed to carry interchangeable payloads, including thermal imagers to give a view of the night scene in total darkness. It can be rapidly directed from side to side and downwards in synchronism with the pilot's head movement. By projecting an image of night scene into the pilot's eye via his helmet-mounted display, he can see in the dark, wherever he happens to be looking, including straight downwards. The system has an exceptionally fast response (over 100 per second) to directional commands and is highly stabilised against the effects of helicopter vibration and its movements in pitch and yaw. The platform has been constructed to the stringent standards already proven with the Heli-Teli daylight viewing system, now in service in several nations.

7.41 Night Vision for Choppers (INFANT System)

A night vision system that gives a helicopter crew the ability to swoop down out of a black sky and locate an enemy in the starlight has been developed by the Army Electronics commands Night Vision Laboratory, Fort Belvoir, Va. The new system uses combination of the latest developments low-light-level TV, image intensifier tubes, fibre optics and covert illuminators to present an image almost as bright day in the cockpit of the helicopter.

The system called INFANT (Iroquois Night Fighter and Night-Tracker), has been installed in a UHM Iroquois helicopter and successfully demonstrated during night operations in the California desert.

The equipment uses two sensors mounted on the front of the helicopter each serving a different viewing system. A remote system, using a low-Iight-level TV, presents an image on three cockpit displays to the crew. The other, a direct-view system using an image intensifier, transmits an image to the copilot gunner through a fibre-optical cable.

7.42 Night Sight for Helicopter

An infrared night sight that enables a gunner to see ground targets in total darkness has been built for the US Army's armed helicopter. The new sight forms an image from infrared radiation given off by objects to present a picture to the gunner nearly as clear as he would see in daylight. The system, called "Passive Infrared Night Equipment" (PINE), consists of an advanced infrared sensor and processing and display electronics. The output from the PINE equipment is electronically fed into the gunner's sight so that by flipping a switch, the gunner can change from a daylight image to the infrared formed thermal image as darkness descends.

The infrared sensor is installed in the swiveling gunner's station and turns with the gunner as he scans a combat area. After locating a target in his sight, the gunner is able to fire any armament he selects, assisted by a computerized fire control system and laser rangefinder .

7.43 Night Viewer for Drivers

A new night driver's viewer, AN/VVS-2, suitable for use by army on combat vehicles, has been developed by Baird-Atomic, USA. The viewer has been fully tested and approved for M60 tanks and M113 Armoured Personnel Carriers. The viewer allows the driver to maneuver without difficulty during visibility or darkness. It is a passive system using an image intensifier to amplify the available light upto 50,000 times. The device features a binocular display which allows the driver to look with both eyes into a 4 inch (10 cm) diameter glass eyepiece from a distance of 2-12 inch (5-30.5 cm).This decreases eye fatigue and minimizes the risk of facial injury when travelling over rough terrain. The viewer has a wide field of view (+45° horizontal by 38° vertical) and focussing is from 1 ft (30.5 cm) to infinity. The system provides unity gain. Its periscope configuration allows the driver to operate with maximum closed hatch safety even under the most severe terrain and visibility conditions.

7.44 Night Vision Device (Electronic Starlightscope)

An electronic starlightscope that can be fitted on top of the rifle of a front line soldier to enable him to see in almost complete darkness has been developed in USA. The key element in the device is a light-intensification tube which magnifies available light 40,000 times, making viewed objects as clear as in daylight. Night light from stars, moon or even skyglow is collected by an outer magnifying lens. This feeble light then passes through , a glass fibre lens whose back is coated with a chemical film that emits electrons when light strikes it. These electrons pass through a 15000 volt electrical field which accelerates them and strengthens the force of the electron beam.These form an image on a second fibre optic lens. The process is repeated twice more, intensifying the electron beam each time. Finally the electrons strike a phosphorus-coated lens and produce a light image like that on a TV screen. The device sends out no radiation of its own, hence it cannot be detected by the enemy.

The starlightscopes are available in three sizes: the smallest starlight scope is for use as a hand-held viewer or for mounting on light infantry weapons.It weighs about six pounds, is nearly 18 inches long and has a housing diameter of three inches. It has a range of upto 1200 feet and four-power magnification. The middle size starlightscope is for heavy-weapon crews and the largest is a medium-range device for use at night observation posts or in aircraft. All the starlightscopes use a power supply that obtains 45000 volts from a 6.75 volt battery in three stages.

7.45 Thermal Image (IR 18)

A thermal imager, IR 18, which is significantly smaller and lighter than its predecessors has been developed by Barr and Stroud, UK. Initially it is expected to play a vital role in extending the operation of a weapon-control system to the hours of darkness. This imager can be integrated with vehicle mounted weapons and installed in submarine periscopes. It could also be used by security organizations. A thermal imager detects objects by using its heat emissions which produce a television type display, on which warm items appear light in colour, while the cooler ones appear darker. The unit can work in complete darkness and can penetrate mist or haze which reduces normal vision.

The imager weighs only 8.5 kg and is only 39 cm long. It has a 6-times magnification telescope, scanner, electronics unit and cooler. The patented scan mechanism, using two rows of cadmium-mercury-telluride detectors scanned in series, contributes to the small size of the imager. This mechanism is cheaper and more reliable than the alternative multiple-row or parallel scan designs. The imager can resolve temperature differences of only 0.25oC.

7.46 Closed Cycle Cooler for Thermal Night Sights

The current cooling system for the man-portable common thermal night sights consists of bottles of compressed dry air that are actuated by a thermostat, a nickel cadmium battery to power the device when it is not being powered by a vehicle and a vehicle power conditioner to be used when it is mounted on a vehicle. This system provides power and cooling for the sights for about two hours before the coolant bottles and batteries have to be replaced.

A new closed cycle cooler, which is intended to replace the current system, has been developed by the US Infantry Board. The system consists of an electrically operated mechanical cooler, battery pack, vehicle power conditioner and power cables. It is designed to provide adequate cooling for the TOW night sight (AN/TAS-4) and the long-range night observation device (AN/TAS-6) for 10-12 hours before the battery must be replaced.

The cooler operates indefinitely if it is powered by a vehicle's electrical system. The test soldiers used the new system with the AN/TAS-4 and the AN/TAS-6 during a series of target detection and recognition exercises. The targets consisted of single and multiple, moving and stationary, wheeled and tracked vehicles and dismounted personnel at ranges upto 2400 m. The exercises were performed from ground mounts as well as from wheeled and tracked vehicle mounts. Although emphasis was placed on night testing, some testing during daylight hours was also conducted with artificial (smoke) obscurants.

7.47 Infrared Imaging Seeker

An infrared imaging seeker for the Maverick missile has been developed and tested for operation in winter conditions by Hughes, USA. The new seeker is intended to detect targets at night and through smoke or haze. Scanning the terrain, the nose mounted seeker produces a TV-style image by sensing minute differences in the infrared energy emitted by objects in the a field of view.

Targets. such as tracked vehicles, trains and trucks show clearly against the background terrain due to the infra- red energy emitted by their engines and structure. The infrared picture enables the pilot to distinguish live targets from dead hulks, fires or decoys at night or in poor visibility.

During the tests in Germany, normal squadron pilots flew sorties in F-4s, A-7s and A-IOs with captive missiles but did not carry out any firings. The seeker is compatible with the Air Force GBU-19 Glide bomb and Navy Walleye smart bomb.

7.48 Night Aiming Device for Shooters

A shooters' aiming device for use at night, called the Bar-Dot sighting system, has been developed by Caswell Equipment Company of Minneapolis, USA for installation on police and military handguns and riot shotguns. The system does not affect the use of conventional sights for day-time firing and has been so designed that it does not basically alter or change the sights on the weapons.

The Bar-Dot sight picture presents a short white bar on which is centered a round white ball, hence the name. Both bar and dot are manufactured from radioactive materials that glow in the dark, producing a clear, positive, white appearance without fading or fluctuating and without iridescence.

7.49 Weston Optronics New Image Intensifier

A new image intensifier sight for small arms has been introduced by Weston Optronics. Designated 'WINS-180l' , it is a high performance night sight which enables a rifleman to select and fire at targets within his normal tactical engagement range at night. The weapon is aimed by using an illuminated aiming graticule which is injected into the eyepiece and superimposed on the field of view. The graticule may take the form of a cross, inverted V, spot or other mark depending on the customer's requirement. Red, orange or yellow illumination is used to give visual contrast with the standard green night vision picture. The sight weighs slightly over 1 kg and it can be fitted to most rifles. By using a pistol grip, the sight can also be used as a hand-held night viewing aid.

Civilization is a progress from an indefinite, incoherent homogeneity towards a definite, coherent heterogeneity .

Herbret Spencer

There is one above Who worketh in all things, and who governs even in the midst of that misrule to which the tendencies and powers of men are so easily perverted.

Michael Faraday

8. DEVELOPMENT ON NVDs IN INDIA

In late 1950s, a need was felt to equip the Indian Army with an effective night vision device which could provide .tactical advantage, night mobility and effective engagement of the enemy during night operations, without being detected by the enemy unaided by special equipment. At the instance of users, the Instruments Research & Development Establishment (IRDE), Dehradun under DRDO was assigned the task of designing and developing night vision devices. The first of the infrared instruments developed by the IRDE, Dehradun for Indian Army are
of active type which utilise an artificial source of infrared radiation to illuminate the target for observation and are based around a photo-electronic image converter tube.

This artificial source of IR radiation can be detected by the enemy with infrared detection systems and, therefore, is not considered safe to use. To overcome this drawback, the development of a new family of passive night vision devices was taken up by the IRDE. These passive devices use photo-electronic image intensifier tubes, which can amplify the intensity of light collected from the low light level scenes of night ambient illumination conditions, by specially designed optical systems. The optical system and image intensifier tube integrated to make a passive night vision instrument, can increase the light amplification of the low light level scenes by many thousand times, so that the human eye can discern various types of objects. No artificial source of illumination is required for these instruments, as they can operate with the scene illumination due to the star light and/or moon light. Besides being safe from the point of view of detection by the enemy, these passive instruments provide large area vision of night scenes compared to the very limited vision provided by the active IR devices, wherein the vision is essentially limited only tom the area being illuminated by a restricted beam from the IR source.

To meet. the specific requirements of the services, the following passive night devices have been developed at IRDE:

(a) Passive Night Observation Device (for battlefield surveillance)

(b) Passive Night Sight for Weapon (for use with an Infantry Weapon for effective engagement of enemy armour at night),

(c) Passive Night Sight for Driver of an Armoured Vehicle (for night driving) and

(d) Passive Night Vision Binocular (for night surveillance)

The above-mentioned instruments have been accepted by the users. Arrangements are being made for transferring new technologies involved in the production of these electro-optical devices to different production agencies in the country for their bulk production. The new types of sights can be effectively used by the artillery for surveillance of battlefield at night; detection of enemy movement and direction of artillery fire. Long range penetration patrols, stay-behind parties, raiding parties and important observation posts of the infantry can also use this sight. The sight alongwith its mount provides an all-round traverse in azimuth and same movement in elevation.

8.1 Infrared Sniperscope

The Infrared Sniperscope is intended to help the sniper to take an accurate and effective aim of the target at much longer ranges than is otherwise possible, without revealing his own position to the enemy. Work was undertaken at IRDE, Dehradun to develop it indigenously on account of its immense defence applications. The equipment consists of an infrared telescope mounted on a rifle, an infrared lamp mounted on the telescope and a high voltage power pack carried on the back of the sniper.

The underlying principle of the instrument is to send out invisible infra-red radiation from an infrared source fitted with a suitable filter to cut off the visible light. The image of the target illuminated by this radiation is collected by the telescope on one end of a special device called the image converter tube. The latter converts the invisible infrared image into a visible green image at the other end. An eyepiece system magnifies this green image and the target is thus clearly seen. As all the radiation outside the telescope is infrared, the sniper or his equipment cannot be seen by the enemy unless the latter is similarly equipped. The image converter tube is operated by the application of very high voltages which are supplied by an indigenously designed power pack. The power pack and the source of illumination are fed from a 6 volt battery. The instrument has been modified for use with the indigenous semi-automatic rifle. The new telescope designed provides for a magnification X3.5 and a field of view of 5 degrees. It is incorporated with a mechanism to a cater for.engaging moving targets, is light in weight (13 OZ2) and compact, but rugged in design. In addition to enhancing the detection and engagement capability, this instrument helps the sniper to break through the normal methods of camouflage of the enemy. The performance of the instrument is at its best during really dark nights; the darker the better. It is, therefore, considered to be a great boon to the sniper in the dark deep jungles. It is fully tropicalised.

8.2 Day-cum-Night Sight for Chetak

DRDO has embarked upon development of a Main Battle Tank (MBT) for the Indian Army which is contemporary, of advanced design and could match any other tank in the world. The Day-cum-Night Sights for this tank are being designed and developed at IRDE, Dehradun. These sights are integrated and could be used during day as well as night. They involve high technology servo stabilization, both in the horizontal and the vertical plane. They will be integrated with the Laser Range Finder (LRF) so that their common transmitting and receiving channel is always aligned with the line of sight. Coupling the sight with the LRF considerably enhances the accuracy of shooting. Prototypes of these instruments have been developed.

8.3 Driver's Passive Night Periscope

The Driver's Passive Night Periscope is required to provide the night vision capability to the driver for driving at night in closed down position. It is to be replaceable with the Day Light Periscope. A system has been designed using second generation Image Intensifier Tube and with the biocular eyepiece, which enables observation with both eyes. Mounting of the night periscope in tilted position compensates for the difference in the eye levels between day and night periscopes.

A Passive Periscopic Night Sight, providing horizontal Field of View (FOV) of 50° and vertical FOV of 17° with unit magnification, using micro-channel image intensifier tube (MCIIT), for use by driver of Vijayanta and MBT tanks has been successfully developed. The design of these periscopes incorporates a suitable fast optical system and binocular eyepiece. Improved prototypes incorporating bright light protection, better optical performance for near objects and angular eyepiece system have been successfully developed.

8.4 Night Vision Goggles

Night Vision Goggles which can be worn by the observer on his head have been designed at IRDE, Dehradun. These night vision goggles are an aid to viewing under low light conditions for the purpose of surveillance, reconnaissance, map reading, etc. This is a very lightweight equipment, as it uses only one objective and one 18 mm wafer image intensifier tube. However , for comfort of viewing, two eyepieces have been provided. The night vision goggles utilise the 'State of Art' technology and are comparable in all aspects with the foreign make goggles.
These can be conveniently mounted on to a face mask and swung out when not in use. A small IR source is provided for short distance viewing like maintenance of vehicles, map reading, etc. It provides a field of view of 35° at unit magnification. The prototype of IRDE designed goggles have been developed.

8.5 Passive Night Vision Binocular

IRDE has designed and developed a hand held Passive Night Vision Binocular for general observation purposes. This binocular has a wide aperture, fast optical system (F/1.3) which considerably enhances its usefulness. It has a Micro Channel Image Intensifier tube which makes it compact and light weight. The binocular has the capability of long distance vision even under adverse night illumination conditions, when the range of the unaided eye is limited to a few metres only.

8.6 Night Sight for Anti-Armour Role

With a view to enhancing the tactical effectiveness of the anti-armour weapons of during night operations, a suitable weapon sight has been developed by IRDE, Dehradun. It is contemporary in nature and compares well with similar equipment made in other countries. The sight has a wide aperture catadioptric fast optics which enhances its operational range. The system uses an Image Intensifier tube to brighten the scene under night illumination conditions. The sight is based upon the state-of-art technology, both optical and mechanical. The prototypes have been successfully produced. Development of this sight has made the country self-reliant in a major area of defence hardware.

8.7 Night Observation Device

A Passive Night Observation Device has been developed successfully for use by Artillery Units in different roles in plains, as MK I equipment. A lighter version of the same is MK II device which will be more suitable for use in mountains.

This passive night observation device may be used by the Artillery for surveillance of battlefields, direction of Arty fire and also for use by long range penetration patrols, stay behind parties, raiding parties and important posts of the Infantry. The sight has a long range capability for detection of personnel, movement of vehicles and engagement of targets by Artillery Units. The device is to be so mounted on a stand that observations can be made from 0 to 360 degrees in Azimuth and from -5 to 40 degrees in elevation. The sight is light in weight and compact
in design. The prototypes of the equipment have already been fabricated and tried out for performance.

8.8 Passive Crew Served Weapon Night Sight

A passive Crew Served Night Sight suitable for use by Infantry has been developed for providing facility for detection/recognition and engaging of targets during night.

It is a compact and lightweight electro-optical device for observation and engagement of targets during night under low light level conditions. The system has been designed around a 140 mm aperture. F/1.1 Catadioptric Mangin Mirror System. The system uses a second generation Microchannel Image Intensification Tube (MCIIT). The prototypes of the sight have been fabricated and are under extensive' evaluation by the Indian Defence Forces. This sight is also being integrated with the Laser Range Finder to improve its tactical efficiency.

8.9 Low Light Level Television (LLTV) System

LLTV system is intended to be used by the Gunner and the Commander of the tank for night vision and fire control. The system consists of a camera, a monitor each for the Commander and the Gunner, a power supply and control unit. A laboratory model of LLTV camera was evaluated using ISIT tube and an F/l catadioptric objective. The system provides a long detection range for armoured fighting vehicle size target under clear star light conditions and covers a large field of view. For tactical reasons, the sight is slaved to some other movements in the tank.

The use of monitor allows sighting with greater comfort and less fatigue to the crew of the tank. Two prototypes of LLTV systems have been fabricated and are presently under extensive evaluation.

8.10 Thermal Imager

The Thermal Imager is intended to be used by the defence forces for search, detection and identification of military targets during day and night operations. This instrument gives better performance as compared to the image intensification tube based instruments, especially for camouflaged objects and under adverse climatic conditions.

It operates in the 8-14 micron region of the energy spectrum and is capable of producing real time thermal images of military targets of interest. A thermal imaging sight for use by the tank is under development at IRDE. The system developed may replace the LLTV camera system presently being envisaged for the role.

Thermal imager would consist of an opto-mechanical scanner, a large aperture fast collecting optical system, an array of multi-element cooled detectors sensitive in the region of 8-14 microns, special signal processing circuits and display techniques for real time picture presentation. The system as a whole will cover an area of about 10º x 5º with an instantaneous field of view of a fraction of a milliradian.

"The story of man's progress is a continual struggle from darkness
to light, once man ceases to know, he ceases to be."

Nansen