

## Appendix 1 – EXPANDED INFORMATION

These definitions are based on MAWTS-1 (1998) and Jones and Shwalier (1998).

**ABSORBANCE** – The ratio of the radiant energy absorbed by a body to that incident upon it.

**ACUITY** – The human eye has a nominal resolution of 1 minute of arc. The common measure of visual acuity is based on reading letters with 1 minute line width, Snellen letters, or patterns with similar detail, such as Landolt rings. Visual acuity is reported as a fraction. The denominator is the test distance (usually 20 feet). The numerator is the relative size of line that can be resolved. That is, 20/40 indicates that the resolution was 2 minutes of arc, twice the nominal value. In other words, that individual can resolve at 20 feet what a “normal” person can at 40 feet.

**AIDED** – A term used to describe those times when NVGs are being used as an aid to night vision.

**ALBEDO** – The ratio of the amount of light reflected from a surface to the amount of incident light.

**ASTRONOMICAL TWILIGHT** – The period of time, beginning in the morning and ending in the evening, when the center of the sun is 18 degrees below the horizon. After astronomical twilight in the evening, the sun does not contribute to sky illumination.

**AUTOMATIC BRIGHTNESS CONTROL (ABC)** – One of the automatic gain control circuits found in second and third generation NVG devices, this feature automatically reduces voltage to the microchannel plate to keep the image intensifier’s brightness within optimal limits and protects the tube. The effect of this can be seen when rapidly changing from a low light to high light conditions. The image gets brighter and then, after a momentary delay, dims to a constant level.

**AUTOMATIC GAIN CONTROL (AGC)** – Comprised of the automatic brightness control and bright source protection circuits. Is designed to maintain image brightness and protect the user and the image tube from excessive light levels. This is accomplished by controlling the gain of the intensifier tube.

**BLACK SPOTS** – These are either cosmetic blemishes in the image intensifier or dirt or debris between the lenses. Black spots that are in the image intensifier tube do not affect the performance or reliability of the night vision device and a number of varying sized spots are inherent in the manufacturing process. Spots due to dirt or debris between the lenses should be removed by careful cleaning if the system is designed for interchangeable optics.

**BLACKBODY** – An ideal surface that completely absorbs all radiant energy falling upon with no reflection.

**BLOOMING** – Common term used to denote the “washing out” of all or part of the NVG image due to de-gaining of the image intensifier tube when a bright light source is in or near the NVG field of view.

**BRIGHT SOURCE PROTECTION (BSP)** – An electronic function that reduces the voltage to the photocathode when the night vision device is exposed to bright light sources such as room lights or car lights. BSP protects the image tube from damage and enhances its life. However, BSP may have the effect of lowering resolution when it is functioning.

**BRIGHT SPOTS** – These are signal- induced blemishes in the image area caused by a flaw in the film on the MCP. A bright spot is small, non-uniform, bright area that may flicker or appear constant.

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Bright spots usually go away when the light is blocked out. Not all bright spots make the ANVIS unserviceable. A test can be performed as follows: Place a cupped hand over the lens to block out all light. Make sure any bright spot is not simply a bright area in the viewed scene. If the bright spot remains, an emission point exists and needs to be checked.

**BRIGHTNESS GAIN** – When referring to an image intensification tube, brightness gain is the ratio of the brightness of the output in units of foot-Lambert, compared to the illumination of the input in foot-candles. A typical value for a GEN III tube is 25,000 to 30,000 FI/fc. A tube gain of 30,000 FI/fc provides an approximate system gain of 3,000. This means that the intensified NVG image is 3,000 times brighter to the aided eye than to the unaided eye.

**BROWNOUT** – Condition created by blowing sand, dust, etc., which can cause the pilots to lose sight of the ground. This is most commonly associated with landings in the desert or in dusty landing zones.

**CHICKEN WIRE** – An irregular pattern of dark lines in the Field-of-View (FOV) throughout the image area or in parts of the image area. Under the worse condition, these lines will form hexagonal or square-wave shaped lines.

**CIVIL NAUTICAL TWILIGHT** – The period of time, beginning in the morning and ending in the evening, when the center of the sun is 6 degrees below the horizon. Illuminance level is approximately 3.40 lux and is above the usable level for NVG operations.

**COLLIMATION** – The act of making rays of light travel in parallel lines. Also the process of aligning the various internal optical axes of a system with each other.

**CONVERGENCE** – The shifting of an observer's eyes inward to view a nearby object, i.e. crossing the eyes.

**COUNTERWEIGHT SYSTEM** – Counterweight systems are used to adjust the center of gravity of the pilot's flight helmet with goggles installed. Without counterweights, there can be a fatiguing forward and downward force on the pilot's neck. The counterweight system may consist of a weight bag and counterweights. The Army's recommended initial weight is 12 ounces for one of its systems. Pilots are instructed to add or remove weight to achieve the best balance and comfort, not to exceed 22 ounces. Attachment of the weight bag is below the back of the helmet with the battery pack mounted vertically above it. The adjustment of the weight is to be made with the binoculars attached and flipped down.

**CYCLES PER MILLIRADIAN (CY/MR)** – Units used to measure resolution. A milliradian is the angle created by one yard at a distance of 1,000 yards. This means that a device that can detect two 1/2 yard objects separated by 1/2 yard at 1,000 yards has a resolution of 1.0 cy/mr.

**DEGRADED VISUAL ENVIRONMENT (DVE)** – Generally DVE conditions refer to any phenomenon which reduces the pilot's vision. Under the traditional definition, NVGs qualify as a degraded visual environment largely due to the goggle's reduced field of view. In terms of a degraded NVG visual environment, it would consist of night conditions during which the pilot has difficulty using the NVGs. Scintillation or visual obscurations that are (or forecast to be) present pose extra pilot workload. Pilots should always be cognizant of the dangers associated with these types of conditions. For example: a new moon combined with overcast skies and very little cultural or reflected lighting.

**DIOPTER** – A measure of the refractive (light bending) power of a lens. The unit of measure used to define eye correction or the refractive power of a lens. Usually adjustment to an optical eyepiece accommodates for differences in individual eyesight. Many military systems provide +2 / -6 diopter range.

**DIVERGENCE** – The shifting of an observer’s eyes vertically, one up and one down.

**DISPLACED GOGGLES** – Displaced goggles have the eye pieces displaced from the user’s eyes such that the user can look through the goggles for night vision aiding or can look under, above, or to the sides of the goggles with unaided vision. A pilot wearing this type of goggle will focus the goggles for far vision, which is required for out of the cockpit viewing. The displaced design has the advantage of allowing pilots to look down under their goggles at the instrument panel or up at their overhead panel without having to first refocus the goggles for near distance. The side viewing allows pilots’ peripheral vision to pick up some peripheral visual cues without having to turn the head.

**DISTORTION** – In an optical system, alterations in the shape of the displayed image as compared to the actual image. Geometric distortion is inherent in all GEN 1 and some GEN II image intensifiers that use electrostatic rather than fibre optic inversion for image inversion.

**DIVERGENCE** – The shifting of an observer’s eyes outward.

**EDGE GLOW** – A bright area (sometimes sparkling) in the outer portion of the viewing area. Edge glow is sometimes caused by an emission point (or series of emission points) just outside the field of view, or by a defective phosphor screen that permits light feedback to the photo-cathode. To check for edge glow, block out all light by cupping a hand over the lens. If the image monocular assembly is displaying edge glow, the bright area will still show up.

**ELECTROLUMINESCENT (EL)** – Referring to light emission that occurs from application of an alternating current to a layer of phosphor.

**ELECTRO-OPTICS (EO)** – The term used to describe the interaction between optics and electronics, leading to transformation of electrical energy into light or vice versa.

**EXIT PUPIL** – In an optical system, the rays of light passing through the system will be limited by either the edges of one of the components such as the eyepiece lens, or by an internal aperture. The image passing through the entrance side of the optical system is the entrance pupil. The image passing out the exit side is the exit pupil. This image forms a small disk containing all of the light collected by the optics from the entire field-of-view.

**EYE RELIEF** – The distance the eyes must be from the last element of an eyepiece in order to achieve the optimal image.

**EYEPIECE LENS** – The eyepiece lens focuses the image from the fiber optic inverter on to the eye by adjusting for individual eye acuity. There are two eyepiece lens assemblies in current systems; the 15 mm and the 25 mm eyepiece lens assembly. Tests show the larger eyepiece is more effective. This lens assembly is designed to provide some adjustment for the user to compensate for minor vision deficiencies (i.e. diopter adjustment). However, the assembly does not correct for all eye deficiencies and does not replace the need for wearing prescribed spectacles or contact lenses.

**FIBRE OPTIC INVERTER** – A bundle of microscopic light transmitting fibers twisted 180 degrees.

**FIELD OF VIEW (FOV)** – The width or spatial angle of the outside scene that can be viewed through the intensifier tubes measured laterally and vertically. Typical NVGs have a 40° FOV.

**FIXED PATTERN NOISE** – Also referred to as Honeycomb. This is usually a cosmetic blemish characterized by a faint hexagonal pattern throughout the viewing area that most often occurs at high-light

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levels or when viewing very bright lights. The pattern can be seen in every image intensifier if the light level is high enough.

**FLASHING, FLICKERING OR INTERMITTENT OPERATION** – The image may appear to flicker or flash. This can occur in either one or both monocular tubes. If there is more than one flicker, check for loose wires, loose battery cap, or weak batteries.

**FOOT-CANDLE** – A measure of luminance; specifically, the luminance of a surface upon which one lumen is falling per square foot.

**FOOT-LAMBERT** – A measure of luminance; specifically the luminance of a surface that is receiving an illuminance of one foot-candle.

**FULL FACE GOGGLES** – Full face goggles are an earlier goggle form factor. The goggle covers the entire upper face much like swimming goggles or masks. A pilot wearing this type of goggle cannot look under, over, or to the side of the goggles, but must instead move his head up, down, or sideways to see the overhead panel, instrument panel, or objects in peripheral vision, respectively. This creates certain human factors problems for pilots. It is too time-consuming to continually refocus the goggles between far and near viewing. So, pilots have to focus one lens to far distance and the other to near distance and then use only the appropriate eye for viewing outside the cockpit or inside the cockpit, respectively. Full face goggles are not acceptable for civil aviation use.

**GAIN** – When referring to an image intensification tube, the ratio of the brightness of the output in units of foot-lambert, compared to the illumination of the input in foot-candles. A typical value for a GEN III tube is 25,000 to 30,000 FI/fc. A “tube gain” of 30,000 FI/fc provides an approximate “system gain” of 3,000. This means that the intensified NVG image is 3,000 times brighter to the aided eye than that of the unaided eye.

**GENERATION** – The term “generation” is often used to describe the age of the technology used to manufacture the image intensifier tubes. There are currently three generations of tubes described below: Generation I. These intensifier tubes were developed in the 1960’s using vacuum tube technology. They use simple grid shaped electrodes to accelerate the electrons through the tube. They required a full moon to achieve an acceptable level of performance. This tube was characterized by excessive blooming and distortion from light sources in the field of view. GEN I tubes have a light amplification of only 1,000 times in comparison with GEN III tubes at 40,000 times. Operating life was only 2,000 hrs. Generation II (GEN II). These tubes were developed with 1970’s technology and incorporated the first microchannel plate (MCP) application to achieve brightness gain. These tubes could operate satisfactorily with one-quarter moon illumination and exhibit low distortion. They amplified light 20,000 times and had an average operating life of 2,500 hrs. Generation III (GEN III). Generation III tubes were developed in the 1990’s and use Gallium Arsenate (with even deeper sensitivity to the infrared spectrum) for the photocathode and a micro-channel plate for gain. The micro-channel plate is also coated with an ion barrier film to increase tube life. The GEN III tube provides very good to excellent low light level performance and can be used in illumination levels down to starlight only. The image is clean and with excellent contrast, and has a long tube life. The expected life span for the GEN III tube is estimated to be 10,000 hours of operation.

**GOGGLE FORM FACTOR** – The term “goggle form factor” refers to the general physical and mechanical characteristics of the goggles. Traditionally there have been and still are two basic goggle form factors, full face goggles and displaced goggles.

**GOOD VISUAL ENVIRONMENT (GVE)** – Night conditions such that the pilot has little difficulty using the NVG. Any scintillation or visual obscurations that may be present does not pose extra pilot workload.

**HONEYCOMB** – See Fixed-Pattern Noise.

**ILLUMINANCE** – Also referred to as illumination. The amount, ratio or density of light that strikes a surface at any given point.

**IMAGE DISPARITY** – This condition may exist when there is a difference in brightness between the two image intensifier assemblies within the same binocular.

**IMAGE DISTORTION** – This problem is more easily detected in high-light conditions. Image distortion is evidenced by vertical objects, such as trees or poles appearing to wave or bend when the user moves his head vertically or horizontally when looking through the goggles. Ground surfaces in the direction of hover may appear to swell or sink. Distortion does not change during life of an image intensifier. Limits on allowable distortion are an important part of performance specifications since excess distortion can interfere with viewing the image and thus with the operator's ability to perform necessary flight manoeuvres.

**IMAGE INTENSIFIER** – An electro-optic device used to detect and intensify optical images in the visible and near infrared region of the electromagnetic spectrum for the purpose of providing visible images. The image intensifier tube is the component of the NVG that actually performs the intensification process. The image intensifier is composed of the photo cathode, MCP, screen optic, and power supply. It does not include the objective and eyepiece lenses.

**INCANDESCENT** – Refers to a source that emits light based on thermal excitation, e.g. heating by an electrical current, resulting in a very broad spectrum of energy that is dependent primarily on the temperature of the filament.

**INFRARED** – That portion of the electromagnetic spectrum in which wavelengths range from 0.7 microns to 1 millimetre. This segment is further divided into near infrared (0.7 – 3.0 microns), mid infrared (3.0 – 6.0 microns), far infrared (6.0 – 15 microns), and extreme infrared (15 microns – 1 millimetre). A NVG is sensitive to near infrared wavelengths approaching 0.9 microns.

**INTERPUPILLARY DISTANCE (IPD)** – Interpupillary distance is the distance between the centers of the pupils of the eyes when the eyes are parallel. Adjustment provisions for variable IPD should be a feature of the NVG to allow the full image to be seen by the NVG user. The recommended range of adjustment should be at least 57 – 70mm to accommodate an estimated 90% of the potential user population. If no adjustment is provided, then the exit pupil must be large enough for the user to get a full field of view.

**IRRADIANCE** – The radiant flux density incident on a surface. For the purpose of this document the terms irradiance and illuminance shall be interchangeable.

**LIGHT INTERFACE FILTER (LIF)** – An optical filter that protects the NVG device and its user from some laser hazards. The LIFs, if installed, are mounted on an adapter attached to the end of the objective lens.

**LINE PAIRS PER MILLIMETER (LP/MM)** – Units used to measure image intensifier resolution. Usually determined from a 1951 Air Force Resolving Power test target. The target is a series of

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different sized patterns composed of three horizontal and three vertical lines. The lines and spacing between lines in each of the different patterns differ in width; the narrower the width, the greater the resolution is needed to distinguish the lines in a given pattern. Human test subjects must be able to clearly distinguish all the horizontal and vertical lines of a particular pattern in order for an image intensifier to achieve the resolution represented by that pattern.

**LUMEN** – A measurement of luminous flux equal to the light emitted in a unit solid angle by a uniform point source of one candle intensity. The unit denoting the photons (light) perceivable by the human eye in one second.

**LUMINANCE** – The luminous intensity (reflected light) of a surface in a given direction per unit of projected area. This is the energy used by NVGs.

**LUX** – A unit measurement of illumination. The illuminance produced on a surface that is one-meter square, from a uniform point source of one candle intensity, or one lumen per square meter.

**MICROAMPS PER LUMEN (A/LM)** – The measure of electrical current (A) produced by a photocathode when it is exposed to a measured amount of light (lumens).

**MICROCHANNEL PLATE (MCP)** – A wafer containing between 3 and 6 million specially treated microscopic glass tubes designed to multiply electrons passing from the photo cathode to the phosphor screen in second and third generation intensifier tubes.

**MICRON** – A unit of measure commonly used to express wavelength in the infrared region; equal to one millionth of a meter.

**NANOMETER (NM)** – A unit of measure commonly used to express wavelength in the visible and near infrared region; equal to one billionth of a meter.

**NAUTICAL TWILIGHT** – The period of time, beginning in the morning and ending in the evening, when the center of the sun is 12 degrees below the horizon.

**NEAR INFRARED** – The shortest wavelengths of the infrared region, normally 750 to 2,500 nanometres. GEN II operates from around 440 to 950 nanometres.

**NIGHT** – The time between the end of evening astronomical twilight and the beginning of morning astronomical twilight.

**NIGHT VISION DEVICE (NVD)** – An electro-optical device used to provide a visible image using the electromagnetic energy available at night.

**NIGHT VISION GOGGLE (NVG)** – When referring to NVGs used for aviation purposes; a head-mounted, lightweight, self-contained binocular system consisting of two independent monocular intensifier tube assemblies.

**OBJECTIVE LENS** – The objective lens assembly collects the available light energy and focuses it on the photocathode (front end of the image intensifier tube). It is housed in an assembly that is used for distance focusing. A coating is placed on the inside portion of the lens that filters out specific wavelengths, thus allowing the use of properly modified interior lighting.

**OPERATIONAL DEFECTS** – These are defects that relate to the reliability of the image intensifier and are an indication of instability. If identified, they are an immediate cause for rejecting a particular NVG device.

**OUTPUT BRIGHTNESS VARIATION** – This condition is evidenced by areas of varying brightness in or across the image area. The lower contrasts do not exhibit distinct lines of demarcation nor do they degrade image quality. This condition should not be confused with shading.

**PHOSPHOR SCREEN** – The phosphor screen converts electrons into photons. A very thin layer of phosphor is applied to the output fiber optic system, and emits light when struck by electrons. See also Photocathode.

**PHOTOCATHODE** – The input surface of an image intensifier that absorbs light energy and in turn releases electrical energy in the form of an electron image. The type of material used is a distinguishing characteristic of the generations of image intensifiers.

**PHOTON** – A quantum (basic unit) of radiant energy (light).

**PHOTOPIC VISION** – Vision produced as a result of the response of the cones in the retina as the eye achieves a light adapted state (commonly referred to as day vision).

**PHOTORESPONSE (PR)** – See Photosensitivity.

**PHOTOSENSITIVITY** – Also called photocathode sensitivity or photoresponse. The ability of the photocathode material to produce an electrical response when subjected to light waves (photons). Usually measured in microamps of current per lumen ( $\mu\text{A}/\text{lm}$ ). The higher the value, the better the ability to produce a visible image under darker conditions.

**PILOT FLYING (PF)** – The pilot who is in control of the aircraft either by operating the flight controls directly or through the autopilot.

**PILOT NOT FLYING (PNF)** – The pilot who is not operating the flight controls (see PF).

**RADIANCE** – The flux density of radiant energy reflected from a surface. For the purposes of this manual the terms radiance and luminance shall be interchangeable.

**REFLECTIVITY** – The fraction of energy reflected from a surface.

**RESOLUTION** – The ability of an image intensifier to distinguish between objects close together. Image intensifier resolution is measured in line pairs per millimetre (lp/mm) while system resolution is measured in cycles per milliradian (cy/mr). For any particular night vision system, the image intensifier resolution will remain constant while the system resolution can be affected by altering the objective or eyepiece optics, by adding magnification or relay lenses. Often the resolution in the same night vision device is very different when measured at the center of the image and at the periphery of the image.

**SCINTILLATION** – A faint, random sparking effect throughout the image area. Scintillation is a normal characteristic of microchannel plate image intensifiers and more pronounced under low light level conditions. Scintillation is sometimes called video noise.

**SCOTOPIC VISION** – That vision produced as a result of the response of the rods in the retina as the eye achieves a dark-adapted state (commonly referred to as night vision).

**SIGNAL-TO-NOISE RATIO (SNR)** – A measure of the light signal reaching the eye divided by the perceived noise as seen by the eye. A tube's SNR determines the low-light resolution of the image tube, therefore, the higher the SNR, the better the ability of the tube to resolve objects with good contrast under low light conditions. Because SNR is directly related to phosphor efficiency and MCP operating voltage, it is the best single indicator of image intensifier performance.

**SITUATIONAL AWARENESS (SA)** – Degree of perceptual accuracy achieved in the comprehension of all factors affecting an aircraft and crew at a given time.

**SPATIAL FREQUENCY** – The number of features or lines per unit of space.

**STARLIGHT** – The illuminance provided by the available (observable) stars in a subject hemisphere. The stars provide approximately 0.00022 lux ground illuminance on a clear night. This illuminance is equivalent to about one-quarter of the actual light from the night sky with no moon.

**STEREOPSIS** – Visual system binocular cues that are used for distance estimation and depth perception. Three dimensional visual perception of objects. The use of NVGs seriously degrades this aspect of near-depth perception.

**TRANSMITTANCE** – The fraction of radiant energy that is transmitted through a layer of absorbing material placed in its path.

**ULTRAVIOLET (UV)** – That portion of the electromagnetic spectrum in which wavelengths range between 0.1 and 0.4 microns.

**UNAIDED** – Term used to describe those times when NVGs are not being used (i.e. normal night vision is not being aided).

**WAVELENGTH** – The distance in the line of advance of a wave from any one point to the next point of corresponding phase; is used to express electromagnetic energy including IR and visible light.

**WHITEOUT** – A condition similar to brownout but caused by blowing snow.