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Analytical Calculation of Night Vision Goggles Working Range*

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Abstract*: An analytical model for Night Vision Goggles (NVG) working range (detection, recognition and identification range) is presented. A formula for numerical calculation of NVG working range as a function of the parameters of the NVG basic components (IIT and objective) is proposed.*

Keywords*: NVG, detection range, recognition range, identification range, generation of IIT.*

Introduction

The maximum range at which the target can be detected is a critical parameter. There are a number of factors that affect the working range (detection range, recognition range, identification range) of Night Vision Devices (NVDs): the Image Intensifiers Tubes (IIT) generation, the amount of ambient and infra-red light at the scene, the object size and its reflectivity and the objective lens light transmitting properties and its optical magnification. The intrinsic factors or the properties of the NVG itself – the IIT properties and objective lens are very important [1, 2]. Nevertheless the exact the analytical calculations are rarely equal to the practical results, it is important to have formulae depending of as many of these factors as possible. For example the optimization of the NVG is one of these cases where parameters of the NVG should be calculated as variables of some cost function.

Methods for calculation of NVG working range

Developing of NVG is a complex process and it is important to optimize it in respect of the NVG elements and on the basis of some quality function. The quality of the NVG usually is presented by their working range and field of view. The numerical

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calculation of the NVG working range including detection, recognition and identification ranges in function of the parameters of basic components – IIT and objective is the first step is that direction. Some relations between input signal and the device sensitivity – the minimal signal for working of the NVG. That minimal signal depends on the external and internal noise. Using this relations the working range of the NVG, aperture (diameter of the inlet pupil), *F*-number, field of view etc. Two known approaches for the NVG working range will be described.

The first approach [3] consists of the next steps [4]:

1) an equation for the flux Φ (or illumination E) of the useful input signal is formulated as a function of radiation parameters, distribution media and receiving system parameters;

2) device flux sensitivity limit Φ_{min} or device illumination sensitivity limit E_{min} on the device input are to be defined;

3) the necessary signal-to noise ratio $M = \Phi/\Phi_{\text{min}}$ (or $M = E/E_{\text{min}}$) is chosen;

4) using step 1 and 2 for the resolving step 3 an equation is obtained and solved.

The NVG working range R with known parameters of optical system, IIT and fixed ambient light condition, determining by [3] is (in m)

(1) $$R = \sqrt{\frac{3.10^{-8}\tau_{\text{a}}}{M3.4\times10^{-14}}}\ ,$$

where τ_{a} is atmosphere transmittance, M – IIT signal-to-noise ratio.

Using the above mention method and well-known physics dependences the equation (1) is obtained. The equation of the effective flux from the background on the IIT photocathode is:

(2) $$\Phi_{\text{b.ef}} = L_{\text{b}}(\lambda)A_{\text{in}}\omega K_{\text{ph}},$$

where the background brightness $L_{\text{b}}(\lambda)$ is determined as

(3) $$L_{\text{b}}(\lambda) = \frac{E}{\pi}\int_{\Delta\lambda}\rho_{\lambda\text{b}}(\lambda)d\lambda,$$

where E is ambient light illumination,

$\rho_{\lambda\text{b}}(\lambda)$ – background spectral reflection coefficient,

A_{in} – area of the inlet pupil surface;

ω – field of view,

K_{ph} – coefficient of the flux usage from IIT photocathode,

(4) $$K_{\text{ph}} = \int_{\Delta\lambda}\tau_{\text{a}}(\lambda)\tau_{\text{o}}(\lambda)\varphi(\lambda)d\lambda.$$

The coefficients in (4) τ_{a} and τ_{o} are coefficients of the atmosphere transmittance and objective transmittance in the working range of the IIT photocathode, $\varphi(\lambda)$ is its spectral sensitivity.

Replacing $L_{\text{b}}(\lambda)$ in (2) and taking into account that $\tau_{\text{a}}(\lambda) = \tau_{\text{a}}$, $\tau_{\text{o}}(\lambda) = \tau_{\text{o}}$ it is obtained:

(5) $$\Phi_{\text{b.ef.}} = \frac{E.A_{\text{in}}\omega\tau_{\text{o}}\tau_{\text{a}}}{\pi}\int_{\Delta\lambda}\rho_{\lambda\text{b}}(\lambda)\varphi(\lambda)d\lambda.$$

If

$$K'_{b} = \int_{\Delta\lambda} \rho_{\lambda b}(\lambda)\varphi(\lambda)d\lambda ,$$

then finally we get to

(6) $$\Phi_{b.ef.} = \frac{EA_{in}\omega\tau_{o}\tau_{a}K'_{b}}{\pi}.$$

Similarly, for the object with angular dimension ω_{ob}

(7) $$\Phi_{ob.ef.} = \frac{EA_{in}\omega_{ob}\tau_{o}\tau_{a}K'_{ob}}{\pi},$$

where

$K'_{ob} = \int_{\Delta\lambda} \rho_{\lambda ob}(\lambda)\varphi(\lambda)d\lambda$ and $\rho_{\lambda ob}(\lambda)$ are object spectral reflection coefficient.

If an object is in the field of view, the effective flux decreases by equation

(8) $$\Phi'_{b.ef.} = \frac{EA_{in}(\omega - \omega_{ob})\tau_{o}\tau_{a}K'_{b}}{\pi}.$$

Total flux from the object and background is

(9) $$\Phi_{\Sigma ef} = \Phi_{ob.ef} + \Phi'_{b.ef.} .$$

The photocathode will respond on the difference of the flux, from the object and the background:

(10) $$\Delta\Phi_{ef} = \Phi_{\Sigma ef} - \Phi_{ef} = \Phi_{ob.ef} + \Phi'_{b.ef} - \Phi_{b.ef}.$$

As $\omega = A_{b}/R^2$ and $\omega_{ob} = A_{ob}/R^2$ (A_{ob}, A_{b} – object and background areas, R^2 – distance to them), the difference in the light flow is

(11) $$\Delta\Phi_{ef} = \frac{A_{ob}A_{in}\tau_{o}\tau_{a}E}{R^2\pi}\left|K'_{ob} - K'_{b}\right|.$$

Using the contrast between the background and surveillance object $K = \left|K'_{ob} - K'_{b}\right|$ we get the final formula for light flows difference:

(12) $$\Delta\Phi_{ef} = \frac{A_{ob}A_{in}\tau_{o}\tau_{a}E}{R^2\pi}K.$$

The device working limitation is that the effective flux should exceed the limiting light flow by the value of signal to noise ratio M, that is

(13) $$\Delta\Phi_{ef} \geq M\,\Phi_{min\ ph}.$$

From (12) and (13) the final formula for device working range calculating is (in m)

(14) $$R^{*} = \sqrt{\frac{A_{in}A_{ob}\tau_{o}\tau_{a}EK}{\pi M\Phi_{min\ ph}}}.$$

If the parameters of (14) are substituted as:

D_{in} is the diameter of the inlet pupil 20.10^{-3} m;

τ_o – objective transmittance 0.8;

$\Phi_{min.ph}$ – IIT limiting sensitivity 3.4×10^{-12} lm;

E – ambient light illumination 4×10^{-3} lx;

A_{ob} – object (target) area 1 m^2;

K – contrast 0.093 (for broken ground background and standing man in camouflage uniform) we get to the formula (1).

A disadvantage of the described approach is that it does not take in account the IIT limiting resolution and IIT photocathode spectral sensitivity is masked into contrast K.

Another formula for NVD working range (in m) is described in [5]:

(15) $$R^{**} = 3\times10^5\sqrt{\frac{\tau_o\tau_a D_{in} S_\Sigma EK}{M\gamma}},$$

where D_{in} is diameter of the inlet pupil,

τ_o, τ_a – objective and atmosphere transmittance,

S_Σ – IIT luminous sensitivity, A/lm,

E – ambient light illumination, lx,

K – contrast,

M – IIT signal-to-noise ratio,

γ – resolution, rad.

Here the parameters γ (resolution) and S_Σ (IIT luminous sensitivity) are explicitly used but IIT limiting resolution, objective focal length and surveillance object area are not taken into account.

From of the NVG quality optimization point of view the working range calculating should take into account all basic components parameters – IIT limiting resolution, IIT luminous sensitivity, diameter of the inlet pupil, objective focal length and surveillance object area. Usually the NVG working range calculation is theoretical procedure before practical development of the device.

The proposed NVG working range calculation formula

The IIT limiting resolution δ (in lp/mm) correspond to (1/2)δ (in mm). The IIT photocathode must have the same resolution. That means the segment with size x (in mm) will be differentiated on the distance r (in mm) as

(16) $$x = r\,\mathrm{tg}e,$$

where

(17) $$\mathrm{tg}e = \frac{1}{2}\left(\frac{1}{\delta}\right)\frac{1}{f'_{ob}},$$

where f'_{ob} is objective focal length (mm).

Taking into account (14), (15) and (17), it is possible to define the NVG working range (in mm) as:

(18) $$R = \sqrt{\frac{0.07 D_{in} f_{ob}\tau_o\tau_a S_\Sigma \delta EKA_{ob}}{M\Phi_{min\,ph}}},$$

where: D_{in} is the diameter of the inlet pupil, m,

f_{ob} – objective focal length, mm,

τ_a, τ_o – atmosphere and objective transmittance,

$\Phi_{min\ ph}$ – IIT photocathode limiting light flow, lm,

δ_{IIT} – IIT limiting resolution, lp/mm,

S_Σ – IIT luminous sensitivity, A/lm,

M – signal-to-noise ratio of IIT,

E – ambient light illumination, lx,

K – contrast,

A_{ob} – target (surveillance object) area, m^2.

In that way defined formula (18) takes into account all parameters of the basic NVG components (objective and IIT) – aperture (diameter of the inlet pupil), objective focal length, objective transmittance, IIT luminous sensitivity, signal to noise ratio and IIT limiting resolution. The ocular parameters don't affect the NVG working range and are not discussed here.

Detection, recognition and identification range

Three different working ranges of the night vision devices are known:

- **Detection range –** the first step in the process of ascertaining the occurrence of a violation of an arms-control agreement [6];
- **Recognition range** – the determination that an object is similar within a category of something already known; e.g., tank, truck, man [7];
- **Identification range** – discrimination between recognizable objects as being friendly or enemy, or the name that belongs to the object as a member of a class [8].

As the detection, recognition and identification are visual processes, the object have to be detected firstly, then it have to be recognized and after that it will be identified.

Detection, recognition and identification ranges depend upon the target and background characteristics, atmospheric propagation, and sensor performance.

In the late 1950's a Night Vision scientist John Johnson, developed methods of predicting target detection, orientation, recognition, and identification. He used line pairs to analyze the volunteer observer's ability to identify scale model targets and originally developed his criteria to discriminate among various types of military targets: solders, tanks, etc. [9].

Johnson's correlation of bar targets to other objects is used to develop a basic spatial relationship dependence for target acquisition tasks shown in the Table 1 [10].

Table 1. Resolution per Minimum Dimension (line pairs)

Target (broadside)	Detecting *Something is there*	Recognition *It's a tank*	Identification *It's a T72 tank*
Truck	0.9	4.5	8.0
M-48 Tank	0.7	3.5	7.0
Stalin Tank	0.75	3.3	6.0
Half-Track	1.0	4.0	5.0
Jeep	1.2	4.5	5.5
Solder (standing)	1.5	3.8	8.0
105 Howitzer	1.0	4.8	6.0
Average	**1.0 ±0.25**	**4.0±0.35**	**6.4±1.5**

Using the Johnson criteria the formula (18) could be modified to be used for calculating the three types of the NVG working ranges (in m) as follows:

(19) $$R = \sqrt{\frac{0.07 D_{\text{in}} f_{\text{ob}} \tau_{\text{o}} \tau_{\text{a}} S_{\Sigma} \delta E K A'_{\text{ob}}}{M \Phi_{\text{min ph}}}},$$

where instead of target area A_{ob}, a "reduced area" of the target A'_{ob} is defined as:

- $A'_{\text{ob}}=(A_{\text{ob}}/1.5)$ to $(A_{\text{ob}}/0.7)$ – for detection range;
- $A'_{\text{ob}}=(A_{\text{ob}}/3.3)$ to $(A_{\text{ob}}/4.8)$ – for recognition range;
- $A'_{\text{ob}}=(A_{\text{ob}}/5)$ to $(A_{\text{ob}}/8.0)$ – for identification range.

Numerical results for NVG detection, recognition and identification ranges and comparative analysis

The working range of NVG is calculated via (14), (15) and (19) based on the next data:

- Objective characteristics: aperture (diameter of the inlet pupil) 20.10^{-3} m, focal length 25.17 mm and transmittance 0.8;
- Contrast between target and background 0.2;
- Target area 1.17 m^2 (using approximately typical height and width for standing man, namely: (1.8 m × 0.65 m);
- Atmosphere transmittance 0.6;
- Ambient light illumination 0.05 lx, 0.01 lx, 0.001 lx, and 0.0001 lx, i.e. a half moon, a quarter moon, starlight and overcast;
- DEP company IIT – different generations (Gen II, Supergen, SHD-3, XD-4 and XR5) [11].

DEP's IIT Gen II with limiting resolution 50 lp/mm, luminous sensitivity 450 μA/lm and signal-to-noise ratio 16

The calculated results for NVG detecting range R_1 for different light conditions (a half moon, a quarter moon, starlight, overcast) using formulae (15), (19) and (14) are shown in Table 2 and the corresponding graphical representation – in Fig 1.

Table 2. NVG detecting range R_1 (in m)

A'_{ob}	D_{in}	f_{ob}	τ_{o}	S_{Σ}	δ	M	E	τ_{a}	K	(19)	(15)	(14)	(19)vs (15)	(19)vs (14)
1	0.02	25.17	0.8	0.00045	50	16	0.05	0.6	0.2	771.13	782.07	485.41	1%	37%
1	0.02	25.17	0.8	0.00045	50	16	0.01	0.6	0.2	344.86	349.75	217.08	1%	37%
1	0.02	25.17	0.8	0.00045	50	16	0.001	0.6	0.2	109.05	110.60	68.65	1%	37%
1	0.02	25.17	0.8	0.00045	50	16	0.0001	0.6	0.2	34.49	34.98	21.71	1%	37%

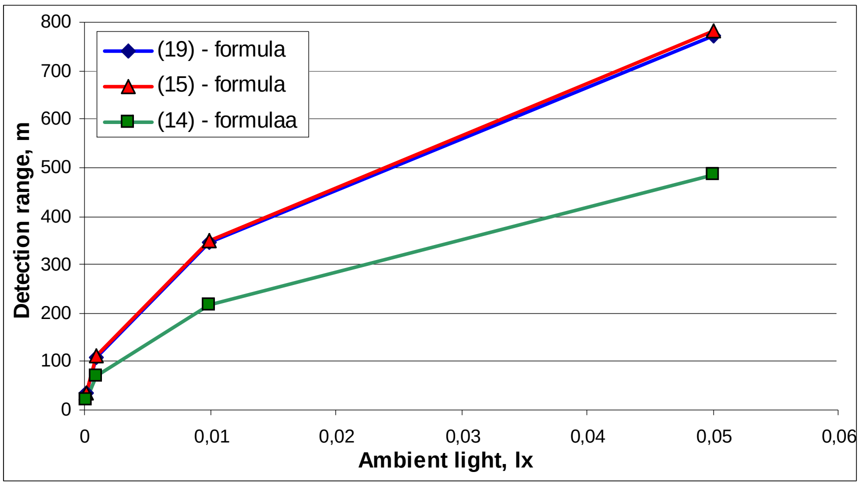

Fig. 1. Detection ranges for the different ambient lighting condition of a half moon, a quarter moon, starlight and overcast

The calculated results for NVG detecting range R_1, recognition range R_2 and identification range R_3 for equal light conditions (a quarter moon and atmosphere tran-smittance 0.6) using formulae (15), (19) and (14) are shown in Table 3 and the corresponding graphical representation – in Fig 2.

Table 3. NVG detecting range R_1, recogntion range R_2, identification range R_3 (in m)

A'_{ob}	D_{in}	f_{ob}	τ_o	S_Σ	δ	M	E	τ_a	K	(19)	(15)	(14)	(19)vs (15)	(19)vs (14)
0.7	0.02	25.17	0.8	0.00045	50	16	0.01	0.6	0.2	292.62	349.75	184.20	20%	37%
0.3	0.02	25.17	0.8	0.00045	50	16	0.01	0.6	0.2	183.85	349.75	115.73	90%	37%
0.1	0.02	25.17	0.8	0.00045	50	16	0.01	0.6	0.2	126.71	349.75	79.76	176%	37%

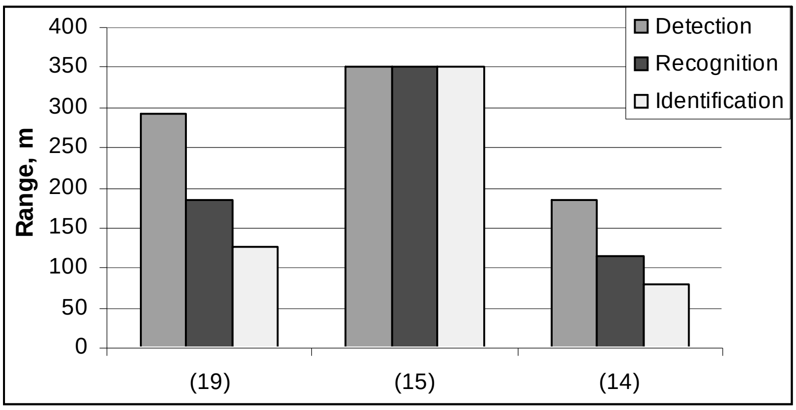

Fig. 2. Detection, recognition and identification ranges for a quarter moon.

DEP's IIT Supergen with limiting resolution 50 lp/mm, luminous sensitivity 550 μA/lm and signal-to-noise ratio 19

The calculated results for NVG detecting range R_1 for different light conditions (a half moon, a quarter moon, starlight, overcast) using formulae (15), (19) and (14) are shown in Table 4 and corresponding graphical representation – in Fig 3.

Table 4. NVG detecting range R_1 (in m)

A'_{ob}	D_{in}	f_{ob}	τ_o	S_Σ	δ	M	E	τ_a	K	(19)	(15)	(14)	(19)vs (15)	(19)vs (14)
1	0.02	25.17	0.8	0.00055	50	19	0.05	0.6	0.2	782.32	793.42	445.44	1%	43%
1	0.02	25.17	0.8	0.00055	50	19	0.01	0.6	0.2	349.87	354.83	199.21	1%	43%
1	0.02	25.17	0.8	0.00055	50	19	0.001	0.6	0.2	110.64	112.21	62.99	1%	43%
1	0.02	25.17	0.8	0.00055	50	19	0.0001	0.6	0.2	34.99	35.48	19.92	1%	43%

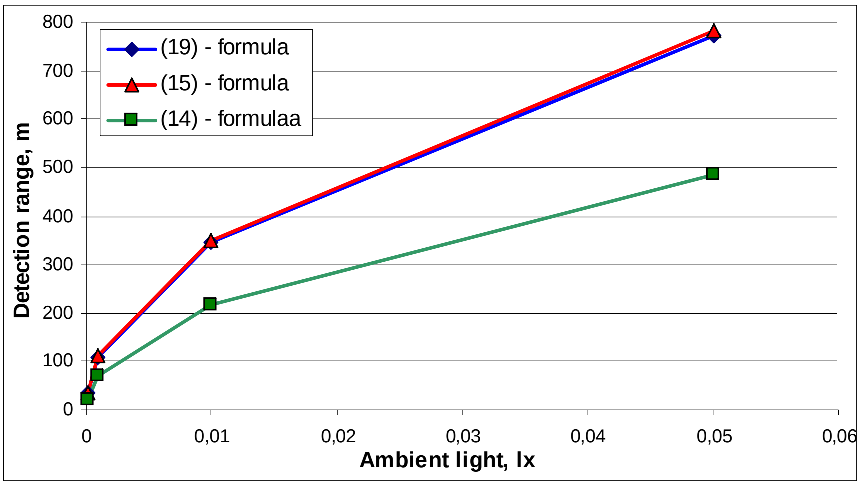

Fig. 3. Detection ranges for the different ambient lighting condition of a half moon, a quarter moon, starlight and overcast

The calculated results for NVG detecting range R_1, recognition range R_2 and identification range R_3 for equal light conditions (a quarter moon and atmosphere transmittance 0.6) using formulae (15), (19) and (14) are shown in Table 5 and the corresponding graphical representation – in Fig 4.

Table 5. NVG detecting range R_1, recogntion range R_2, identification range R_3 (in m)

A'_{ob}	D_{in}	f_{ob}	τ_o	S_Σ	δ	M	E	τ_a	K	(19)	(15)	(14)	(19)vs (15)	(19)vs (14)
0.7	0.02	25.17	0.8	0.00055	50	19	0.01	0.6	0.2	296.87	354.83	169.03	20%	43%
0.3	0.02	25.17	0.8	0.00055	50	19	0.01	0.6	0.2	186.52	354.83	106.20	90%	43%
0.1	0.02	25.17	0.8	0.00055	50	19	0.01	0.6	0.2	128.55	354.83	73.19	176%	43%

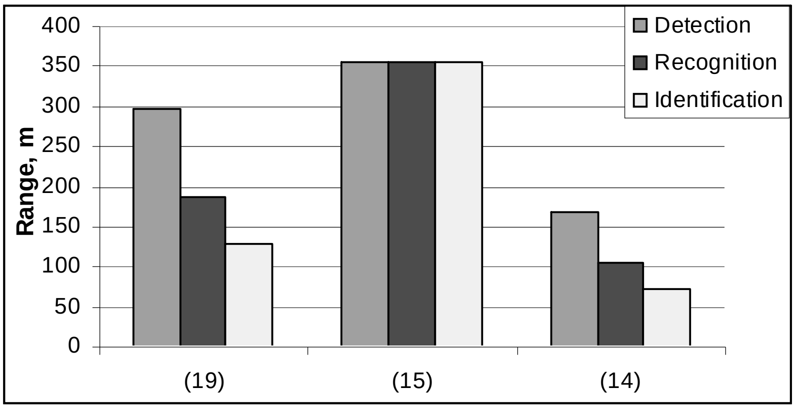

Fig. 4. Detection, recognition and identification ranges for a quarter moon.

DEP's IIT SHD-3 with limiting resolution 54 lp/mm, luminous sensitivity 600 µA/lm, signal-to-noise ratio 20

The calculated results for NVG detecting range R_1 for different light conditions (a half moon, a quarter moon, starlight, overcast) using formulae (15), (19) and (14) are shown in Table 6 and the corresponding graphical representation – in Fig 5.

Table 6. NVG detecting range R_1 (in m)

A'_{ob}	D_{in}	f_{ob}	τ_o	S_Σ	δ	M	E	τ_a	K	(19)	(15)	(14)	(19)vs (15)	(19)vs (14)
1	0.02	25.17	0.8	0.0006	54	20	0.05	0.6	0.2	827.66	839.40	434.16	1%	48%
1	0.02	25.17	0.8	0.0006	54	20	0.01	0.6	0.2	370.14	375.39	194.16	1%	48%
1	0.02	25.17	0.8	0.0006	54	20	0.001	0.6	0.2	117.05	118.71	61.40	1%	48%
1	0.02	25.17	0.8	0.0006	54	20	0.0001	0.6	0.2	37.01	37.54	19.42	1%	48%

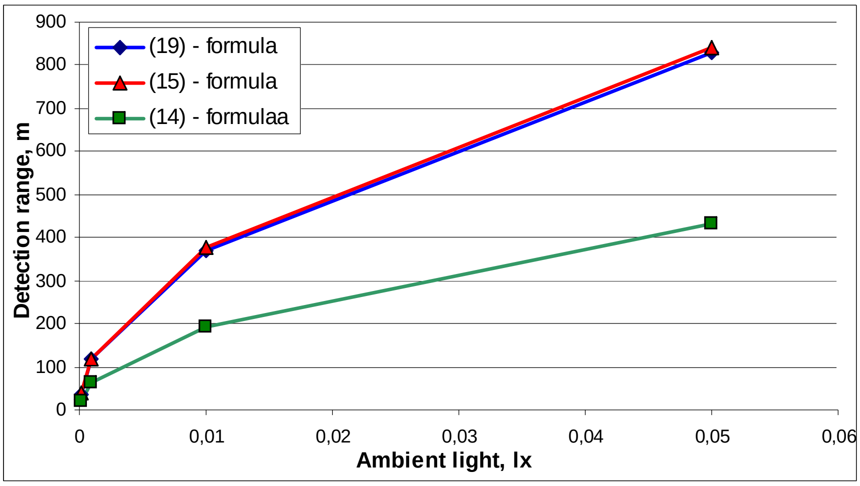

Fig. 5. Detection ranges for the different ambient lighting condition of a half moon, a quarter moon, starlight and overcast

The calculated results for NVG detecting range R_1, recognition range R_2 and identification range R_3 for equal light conditions (a quarter moon and atmosphere transmittance 0.6) using formulae (15), (19) and (14) are shown in Table 7 and the corresponding graphical representation – in Fig 6.

Table 7. NVG detecting range R_1, recogntion range R_2, identification range R_3 (in m)

A'_{ob}	D_{in}	f_{ob}	τ_o	S_Σ	δ	M	E	τ_a	K	(19)	(15)	(14)	(19)vs (15)	(19)vs (14)
0.7	0.02	25.17	0.8	0.0006	54	20	0.01	0.6	0.2	314.08	375.39	164.75	20%	48%
0.3	0.02	25.17	0.8	0.0006	54	20	0.01	0.6	0.2	197.33	375.39	103.51	90%	48%
0.1	0.02	25.17	0.8	0.0006	54	20	0.01	0.6	0.2	136.00	375.39	71.34	176%	48%

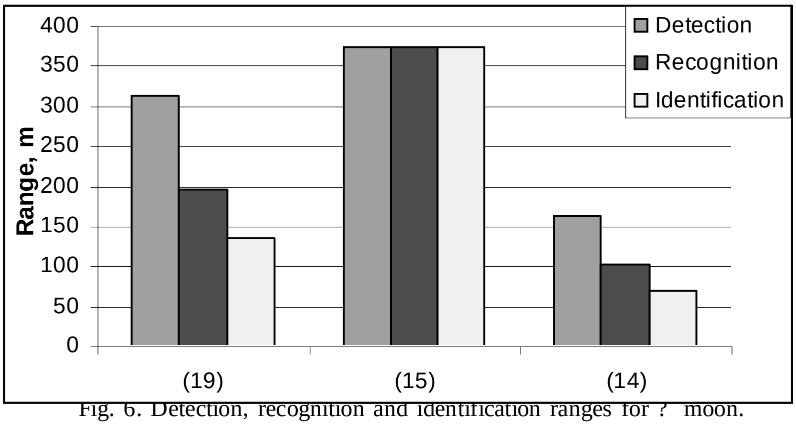

Fig. 6. Detection, recognition and identification ranges for ? moon.

DEP’s IIT XD-4 with limiting resolution *58* lp/mm, luminous sensitivity 700 μA/lm, signal-to-noise ratio 24

The calculated results for NVG detecting range R_1 for different light conditions (a half moon, a quarter moon, starlight, overcast) using formulae (15), (19) and (14) are shown in Table 8 and the corresponding graphical representation – in Fig 7.

Table 8. NVG detecting range R_1 (in m)

A'_{ob}	D_{in}	f_{ob}	τ_o	S_Σ	δ	M	E	τ_a	K	(19)	(15)	(14)	(19)vs (15)	(19)vs (14)
1	0.02	25.17	0.8	0.0007	58	24	0.05	0.6	0.2	845.77	857.77	396.33	1%	53%
1	0.02	25.17	0.8	0.0007	58	24	0.01	0.6	0.2	378.24	383.61	177.25	1%	53%
1	0.02	25.17	0.8	0.0007	58	24	0.001	0.6	0.2	119.61	121.31	56.05	1%	53%
1	0.02	25.17	0.8	0.0007	58	24	0.0001	0.6	0.2	37.82	38.36	17.72	1%	53%

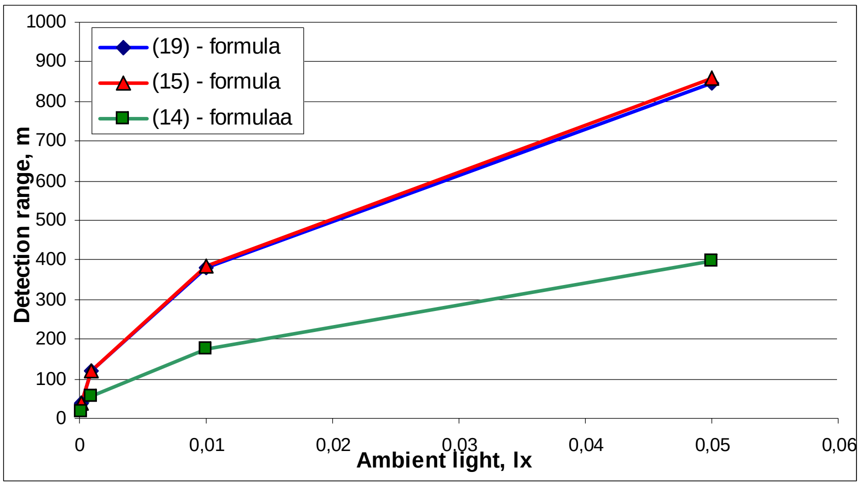

Fig. 7. Detection ranges for the different ambient lighting condition of a half moon, a quarter moon, starlight and overcast

The calculated results for NVG detecting range R_1, recognition range R_2 and identification range R_3 for equal light conditions (a quarter moon and atmosphere transmittance 0.6) using formulae (15), (19) and (14) are shown in Table 9 and the corresponding graphical representation – in Fig 8.

Table 9. NVG detecting range R_1, recogntion range R_2, identification range R_3 (in m)

A'_{ob}	D_{in}	f_{ob}	τ_o	S_Σ	δ	M	E	τ_a	K	(19)	(15)	(14)	(19)vs (15)	(19)vs (14)
0.7	0.02	25.17	0.8	0.0007	58	24	0.01	0.6	0.2	320.95	383.61	150.40	20%	53%
0.3	0.02	25.17	0.8	0.0007	58	24	0.01	0.6	0.2	201.65	383.61	94.49	90%	53%
0.1	0.02	25.17	0.8	0.0007	58	24	0.01	0.6	0.2	138.97	383.61	65.12	176%	53%

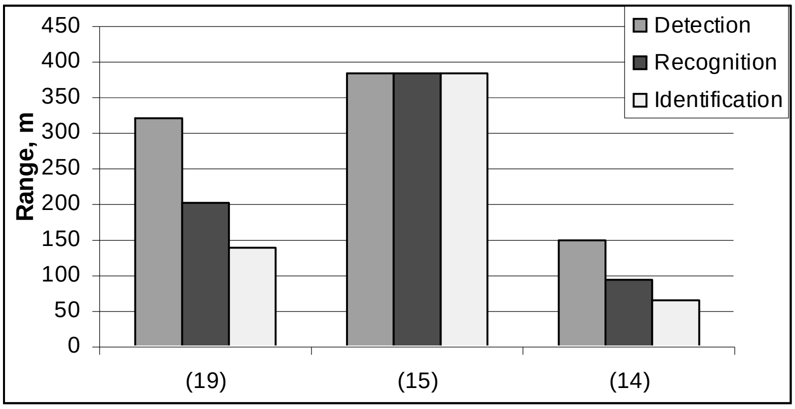

Fig. 8. Detection, recognition and identification ranges for and a quarter moon

DEP's IIT XR5 (Generation 4) with limiting resolution 70 lp/mm, luminous sensitivity 800 μA/lm, signal-to-noise ratio 28

The calculated results for NVG detecting range R_1 for different light conditions (a half moon, a quarter moon, starlight, overcast) using formulae (15), (19) and (14) are shown in Table 10 and the corresponding graphical representation – in Fig 9.

Table 10. NVG detecting range R_1 (in m)

A'_{ob}	D_{in}	f_{ob}	τ_o	S_Σ	δ	M	E	τ_a	K	(19)	(15)	(14)	(19)vs (15)	(19)vs (14)
1	0.02	25.17	0.8	0.0008	70	28	0.05	0.6	0.2	919.63	932.67	366.93	1%	60%
1	0.02	25.17	0.8	0.0008	70	28	0.01	0.6	0.2	411.27	417.10	164.10	1%	60%
1	0.02	25.17	0.8	0.0008	70	28	0.001	0.6	0.2	130.05	131.90	51.89	1%	60%
1	0.02	25.17	0.8	0.0008	70	28	0.0001	0.6	0.2	41.13	41.71	16.41	1%	60%

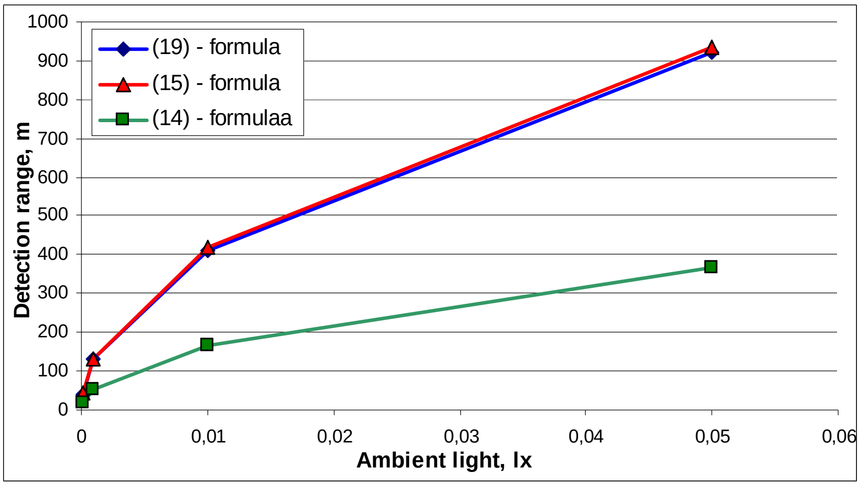

Fig. 9. Detection ranges for the different ambient lighting condition of a half moon, a quarter moon, starlight and overcast

The calculated results for NVG detecting range R_1, recognition range R_2 and identification range R_3 for equal light conditions (a quarter moon and atmosphere transmittance 0.6) using formulae (15), (19) and (14) are shown in Table 11 and the corresponding graphical representation – in Fig 10.

Table 11. NVG detecting range R_1, recogntion range R_2, identification range R_3 (in m)

A'_{ob}	D_{in}	f_{ob}	τ_o	S_Σ	δ	M	E	τ_a	K	(19)	(15)	(14)	(19)vs (15)	(19)vs (14)
0.7	0.02	25.17	0.8	0.0008	70	28	0.01	0.6	0.2	348.97	417.10	139.24	20%	60%
0.3	0.02	25.17	0.8	0.0008	70	28	0.01	0.6	0.2	219.25	417.10	87.48	90%	60%
0.1	0.02	25.17	0.8	0.0008	58	28	0.01	0.6	0.2	137.55	417.10	60.29	176%	60%

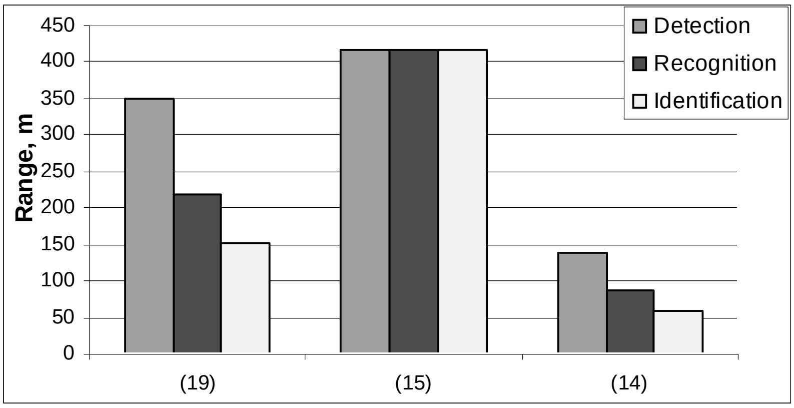

Fig. 10. Detection, recognition and identification ranges for a quarter moon.

The numerical calculations show that:

• The formula (15) is not suitable for recognition and identification ranges estimation because of the fact that it does not take into account the target area. It could be used for detection range estimation for different IIT types. The obtained results by formula (14) give the relative difference of about 37 to 60% because (14) does not take into account the IIT photocathode luminous sensitivity and it's limiting resolution.

• The proposed modifications of the working ranges calculation formula (19) is taking into account all essential parameters and is suitable for estimation of detection, recognition and identification ranges for different IIT types.

Conclusions

The proposed NVG working ranges calculation formula (18) takes into account the most important parameters of the elements of opto-electronics tract. Using the Johnson criteria a "reduced target area" is defined and together with (18) formula (19) is obtained for determine of some types of NVG' working ranges – detection, recognition and identification for different target.

An preliminarily estimation could be done for different types of NVG working ranges on the stage of NVG' opto-electronics tract design, i.e. before prototype producing and testing in real conditions. That formula could be used as element of an optimization criteria for quality of NVG' opto-electronics tract.

References

1. Illustrated Night Vision Guide.
http://www.sovietbazaar.co.uk/hownvworks.htm
2. How Starlight Technology works.
http://www.atncorp.com/HowNightVisionWorks/

3. B o r i s s o v a, D., M. D e k o v, D. K o z a r e v, E. B a n t u t o v, I. I l i e v. Optical- electronic device – night vision goggles – “Prilep”. – Cybernetics and Information Technologies, Vol. **1**, 2001, No 1, 108-115.
4. E l i z a r e n k o, A. S., J. B. P a r v u l j u s o v, V. P. S o l d a t o v, J. G. J a k u s h e n k o. Design of optical electronic devices. Moscow, Machinebulding, 1981. (in Russian)
5. G o e v, A. I. Modernization of devices for night vision. – Specialized Techniques, 2002, No 2. (in Russian)
6. Military Definitions – Detection.
http://www.fas.org/news/reference/lexicon/ded.htm
7. Military Definitions – Recognition.
http://www.fas.org/news/reference/lexicon/Der.htm
8. Military Definitions – Identification.
http://www.fas.org/news/reference/lexicon/dei.htm
9. M i l l e r, J. L., J. M. W i l t s e. Resolution Requirements for Alphanumeric Readability. Optical Engineering, Vol. **42**, March 2003, No 3, 1-6.
10. R u s s e l l, L., J r. L o m b a r d o. Target Acquisition: It’s Not Just For Military Imaging. Photonics Spectra, July 1998, 123-126.
11. Image Intensifiers Tube.
http://www.dep.nl/