

# Advanced Image Intensifier Night Vision System Technologies: Status and Summary 2002

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## ABSTRACT

This paper presents the current status and summary of image intensified night vision system technologies using Northrop Grumman Electro-Optical Systems (NGEOS) advanced image intensifier ( $I^2$ ) tubes and associated NGEOS advanced  $I^2$  technologies. NGEOS advanced  $I^2$  technologies is divided into three fully proven and critical  $I^2$  subtechnologies: Unfilmed microchannel plate (MCP) based  $I^2$ , Autogated power supply technologies, and 16mm halo free  $I^2$  technology. The initial discussion in this paper will center around the three major NGEOS advanced  $I^2$  subtechnologies and their respective night vision system performance benefits. Secondly, this paper will present and discuss the laboratory and field (ground and aerial) performance results from these various advanced night vision systems and technologies. Finally, this paper concludes with the extension and application of the previously noted advanced image intensifier technologies in digital imaging system applications such as image fusion systems combining image intensification and uncooled infrared sensors (SWIR/MWIR/LWIR).

**Keywords:** Image Intensifier, Night Vision Systems, Unfilmed microchannel plate, Autogated power supply, 16mm Image Intensifier, Uncooled Infrared Imagers, Image Fusion

## 1. BRIEF HISTORY OF IMAGE INTENSIFIER GENERATIONS

### 1.1. Anatomy of Image Intensifier ( $I^2$ ) Tube

The basics mechanics of an image intensifier tube is depicted in Figs. 1a and 1b.

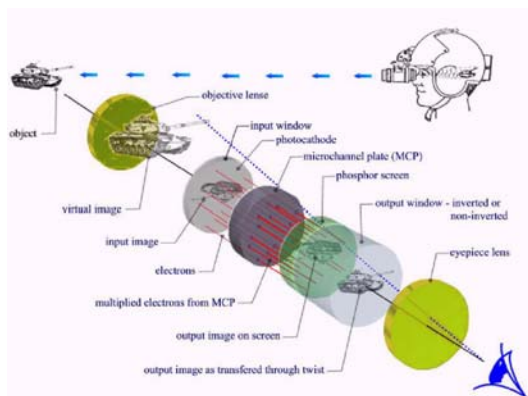


Fig. 1a. Operation of Image Intensified Night Vision System

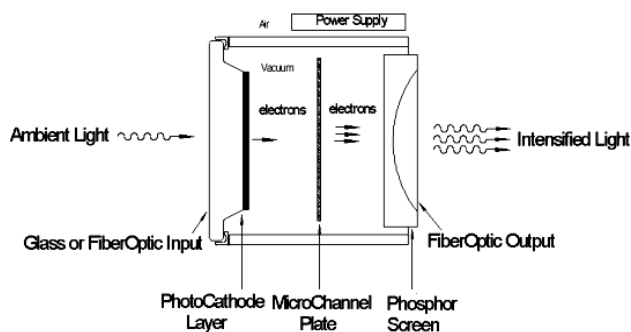


Fig. 1b. Operation of Image Intensifier Tube

Input light from an external object such as a tank is collected and focused by the system objective lens into the input window of the  $I^2$  tube containing its photocathode. At the photocathode, input light photons are converted into electrons. These photogenerated electrons traverse the bulk of the photocathode, escape the surface of the photocathode, and pass through the first vacuum gap of the  $I^2$  tube.<sup>1,2</sup> After traversing the first vacuum gap, the electrons must pass through a thin ion barrier film layer<sup>3,4</sup> as defined in Generation III  $I^2$  tubes, and then these electrons are amplified by the microchannel plate (MCP) to several thousand times through multiple secondary electron forming collisions on the MCP channel walls. These amplified electrons then pass the second  $I^2$  tube vacuum gap to reach a phosphor screen that

converts these electrons to monochromatic light photons. Finally the monochromatic light from the phosphor screen is collected by the night vision system's eyepiece lens and focused into the night vision user's eye to give an intensified image of the original target object. It should be noted that the energy imparted to the free electrons traversing the I<sup>2</sup> tube vacuum gaps is given by a miniaturized wrap around power supply. At present, high voltage I<sup>2</sup> power supply provides thousands of volts of electric field potential to the I<sup>2</sup> tube vacuum gaps with very little current drain (less than 20-40 milliamperes) and draws tens of hours of I<sup>2</sup> tube operation through standard configuration "AA" alkaline battery arrangements.

### 1.2. Synopsis of I<sup>2</sup> Generations

The historic synopsis of I<sup>2</sup> tube generations is found in Table 1. The highest performance I<sup>2</sup> technology in Table 1 is NGEOS "Unfilmed" MCP based I<sup>2</sup>.

**Table 1.** Historical Synopsis of Image Intensifier Generations

Type	Years	Photocathode	Tube Enhancement	PR μA/lumen	Resolution lp/mm
GEN 0	1950's	S-1, Ag-O-Cs	Photodiode	0-5	80-100
GEN I	1960's	S-20 Multialkali	Electrostatic Focus	50-100	22-36*
GEN II	1970's	S-25 Multialkali	MCP (High Gain) Proximity Focus	100-400	22-36
GEN III	1980-90's	GaAs	MCP (High Gain) Proximity Focus	600-1800	36-64
Unfilmed MCP GEN III**	2000	GaAs	Unfilmed MCP	2200	72+

\*Reduced resolution due to three cascading of GEN I image tubes

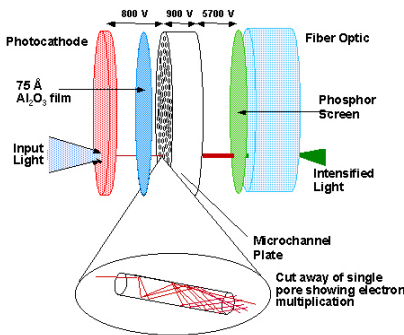
\*\*Auto Gating and Halo Free operations are enhancement to Unfilmed MCP GEN III I<sup>2</sup> technology

The other two NGEOS advanced I<sup>2</sup> technologies, Auto Gated and Halo Free are defined in Table 1 as Unfilmed MCP Generation III I<sup>2</sup> enhancements that may in fact define in full combination as a next generation I<sup>2</sup> technology. As discussed in subsequent sections, NGEOS advanced Generation III I<sup>2</sup> technologies define the present I<sup>2</sup> state-of-the-art and provide tremendous night vision system performance enhancements in the form of significant operational performance in low to high light level conditions.

## 2. NGEOS Advanced I<sup>2</sup> Technologies

### 2.1. Unfilmed MCP I<sup>2</sup> Technology

The core technology element of present enhanced Generation III I<sup>2</sup> device is the Unfilmed MCP. Based on Generation III I<sup>2</sup> technology in Section 1, it was necessary to introduce an ion barrier film to maintain a nominal level of I<sup>2</sup> tube lifetime for the standard Generation III technology. As seen in Fig. 2, the large amount of secondary electron formation through electron-to-MCP wall collisions forms the mechanism for electron amplification in all MCP based I<sup>2</sup> tubes.



**Fig. 2.** Electro-Optical Mechanism for Film/Unfilmed MCP based I<sup>2</sup>

However, these same electron-to-MCP wall collisions dislodge stray adsorbed gases on the surface of the MCP channel walls. These liberated adsorbed gases become positively charged ions that traverse the same electric field lines, traveled by the signal generating electrons, back to the photoemissive photocathode surface, which is in the case of Generation III I<sup>2</sup> tube technology, oxidized cesium on gallium arsenide (GaAs). These positive ions damage the photocathode on contact and degrade the lifetime of the I<sup>2</sup> tube. With increased and continued improvement in GaAs photocathode technology in the last several years, the quantum efficiency (QE) and photosensitivity of the photocathode layer were dramatically increased, but these sensitivity improvements were never realized at either the I<sup>2</sup> tube or system levels because of the ion barrier film. Maximum I<sup>2</sup> tube performance would require the removal of the ion barrier film or having an “unfilmed” MCP. The anticipated fundamental benefits of the removal of the ion barrier is as follows:

- Increased I<sup>2</sup> Signal-to-Noise Ratio (SNR)
- Increased I<sup>2</sup> Resolution
- Reduced I<sup>2</sup> Halo from Bright Source

All the above I<sup>2</sup> performance improvements in turn provide at the system level significantly longer detection/recognition/identification ranges and enhanced visual information. Ion barrier removal in a Generation III I<sup>2</sup> tube is technically not a difficult task, but having an I<sup>2</sup> tube with stable performance and nominal finite lifetime is a true technological feat.<sup>5,6</sup> In fact, this provided the impetus for a U.S. Army Night Vision and Electronic Sensors Directorate (NVESD) to sponsor a development program (DAAB07-96-D-H754) in late 1997 which both NGEOS and ITT Electro-Optical participated to develop a high reliability unfilmed MCP based I<sup>2</sup> tube. The major goals of the NVESD programs are as follows:

- Develop ion barrier free MCP based Generation III I<sup>2</sup>
- Signal-to-noise ratio no less than 27:1 (SNR Goal of 30:1)
- Reliability no less than 7,500 hours
- I<sup>2</sup> Configuration is standard 18mm Gen III Configurations
- Tube and System Deliverables at end of program

As seen in Fig. 3 NGEOS achieved the first reliable unfilmed MCP based I<sup>2</sup> tube with initial field tests of the technology in an AN/AVS-6 aviation night vision goggle conducted by the U.S. Army PM/NV-RSTA.

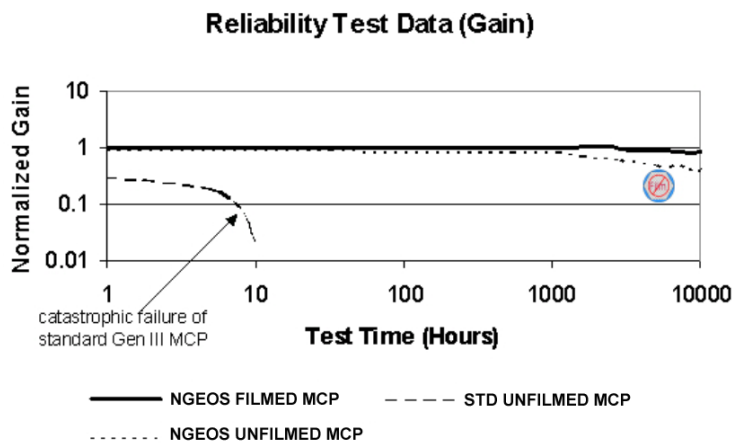


Fig. 3. Comparison of Reliability Test Data for Unfilmed MCP I<sup>2</sup> tube

As anticipated during the development effort in June 1999, NGEOS produced an I<sup>2</sup> tube with a signal-to-noise ratio (SNR) at  $1 \times 10^{-5}$  fL illumination of 32.6:1 measured by U.S. Army NVESD which exceeded the development program goal of 30:1. This milestone measurement was later superseded by another NVESD SNR measurement of a NGEOS unfilmed I<sup>2</sup> tube of 35.83:1 in October 1999. This SNR measurement of a NGEOS unfilmed I<sup>2</sup> tube represents world record low light level performance and a significant milestone for image intensifier technology. With the successful

development of unfilmed MCP based  $I^2$  tube technology by NGEOS and exceeding the performance goals of the NVESD program, the next logical step for this technology was productionization and direct system application in a major U.S. military procurement, U.S. Army CECOM OMNIBUS V and VI programs.

## 2.2. Autogated Power Supply Technology

In parallel development with the Unfilmed MCP based  $I^2$  tube, NGEOS developed an automatic gated power supply. Photocathode cathode gating technology is well known in both military and commercial system applications.<sup>6-8</sup> The main concept behind photocathode gating is turning photocathode voltage on and off at high speeds (milliseconds to nanoseconds) in order to reduce input current (electron) flux from the photocathode to  $I^2$  MCP from excessively high light levels from bright sources or illuminated scenes. In terms of intensified imaging applications, the gating repetition rate exceeds thirty frames per second (30 Hz) in order for the application user's eye not to perceive the photocathode gating pulse. The autogated power supply technology developed by NGEOS makes use of the standard concept of photocathode gating but internally performs the gating duty cycle adjustment to external light level changes automatically. Also, this NGEOS technology provides photocathode gating operations at high voltages (greater than 600 volts) in a power supply configuration that matches the standard commercial 18mm Generation III  $I^2$  tube formats (MX-10130 and MX-10160) which is significant as compared to previous gated power supplies that provide photocathode gating from an external gating trigger, at less than 100 volts, and with larger, nonstandard  $I^2$  package configurations. Besides the automatic capability of this new power supply technology, there are other significant system and image intensifier benefits of this new power supply technology as follows:

- Form, Fit, Function Upgrade
  - MX-10130 Power Supply (AN/PVS-7)
  - MX-10160 Power Supply (AN/AVS-6,9)
- Upgrade Existing Fielded Night Vision Systems
  - Direct Retrofit into Existing Systems
- Increased Dynamic Range System Performance
  - High Resolution Imaging in Daylight
  - High Resolution Imaging in MOUT Conditions
  - Improved System Resolution
- Extended Image Intensifier Life

The imaging performance benefits of automatic  $I^2$  tube gating are illustrated in Fig. 4. Fig. 4 shows that with autogating technology bright source and highlight scene images can be automatically managed to produce high resolution images with “image bloom” reduced bright source information as in the case of the house with multiple bright sources. Also, Fig. 4 shows the ease of upgradeability of this technology into standard night vision systems such as AN/AVS-6,9 type night vision aviation goggle and  $I^2$  devices.

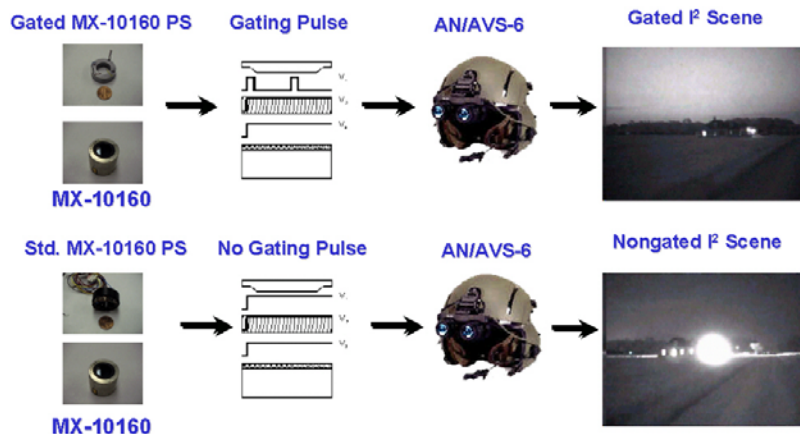


Fig. 4. Illustration of NGEOS Automatic Gating Technology with Bright Source Scene

### 2.3 16mm Halo Free I<sup>2</sup> Technology

In concurrent development with Unfilmed MCP and Autogated power supply technologies, 16mm halo free I<sup>2</sup> tube technology was developed. NGEOS was motivated to develop this I<sup>2</sup> technology in light of mounting user need for next generation night vision systems that provide reduced overall system size/volume footprint to existing night vision systems and enhanced imaging performance based on significant imaging halo reduction.

#### 2.3.1 Reduced I<sup>2</sup> Format (16mm I<sup>2</sup> Technology)

A high performance, small format I<sup>2</sup> can facilitate the development of night vision systems with improved ergonomics. A reduction of the I<sup>2</sup> tube format impacts the size and weight of the entire night vision system as a commensurate reduction in the effective focal length and aperture of the system optics attends. Night vision goggle users benefit from a reduction in head borne weight, forward projection and a more natural position of the systems center of gravity. The technical challenge is to engineer a small format I<sup>2</sup> tube that offsets any performance deficit due to the smaller focal plane.

The NGEOS 16mm Image Intensifier is designed around the precept that performance at the system level must meet or exceed the performance of currently fielded 18mm night vision systems. This mandate poses performance challenges especially in the areas of resolution and halo. The minimum 16mm I<sup>2</sup> tube resolution and halo requirements can be estimated by scaling the performance goal for these spatial parameters by the ratio 16 to 18.

For the case of resolution, it is clear that the resolution of the 16mm tube must be increased relative to an 18mm format device to maintain a given level of performance at the system level for any specified field of view. Given that the current state of the art for 18mm format I<sup>2</sup> tube resolution is 72 lp/mm, the calculate minimum resolution requirement ( $R_{min}$ ) is,

$$R_{min} = 64 \times \frac{18}{16} = 81lp/mm \quad (1)$$

This performance enhancement forces the use of fine pitch geometry in the mosaic components (MCP and Fiber Optic Anode) in the design and construction of the 16mm image intensifier. Careful consideration must also be give to the design of the electrostatic lens elements formed by the vacuum gaps of the I<sup>2</sup> tube.

The I<sup>2</sup> artifact known as halo must also be addressed in the small format image intensifier design. Halo results from the scattering and elastic reflection of photoelectrons at the input surface of the MCP. The trajectory of these electrons depends only upon the size of the vacuum gap between the photocathode and MCP. Since the size of the halo is independent of the I<sup>2</sup> format a halo of a given size obscures more scene information in a 16mm format image intensifier than in an 18mm device. Given that the current state of the art for 18mm format I<sup>2</sup> halo is 0.75 mm, the calculated maximum Halo requirement ( $H_{max}$ ) is,

$$H_{max} = 0.75 \times \frac{16}{18} = 0.67mm \quad (2)$$

This performance enhancement requires the use of a smaller photocathode to MCP vacuum gap for 16mm image intensifier design. We are pursuing a design based upon the NGEOS Halo Free I<sup>2</sup> technology discussed below.

Unfilmed MCP and Autogated power supply technologies round out the technology arsenal that must be applied to the 16mm I<sup>2</sup> design to ensure parity with currently fielded devices. In addition to the obvious low light level imaging performance benefit of unfilmed MCP I<sup>2</sup> technology, it is a prerequisite to implementing the Halo Free feature of the tube. Use of the Autogated power supply technology ensures that the resolution performance of our 16mm Image Intensifier excels in light polluted environments.

NGEOS has made significant progress in the development of a 16mm I<sup>2</sup> tube embodying these performance enhancements. The key accomplishment include the following,

- Completion of the baseline design
- Development of intellectual property
- Device patents issued for novel design and manufacturing approaches
- Installation of a Low Rate Production facility
- Developed Sub-assembly fabrication methods
- Fabrication of prototypes and design verification samples
- Delivery of Advanced Development prototypes under a Government funded program

The key performance demonstrated by the Advanced Development Prototypes is shown below in Fig.5. Future work will focus on the refinement of manufacturing technology and design validation for this device.

	Goal	Actual
Halo	0.67 mm	0.48 mm
Resolution	82 lp/mm	81 lp/mm
SNR	26	28



Fig. 5. Key Performance Goals Were Met by NGEOS Advanced Development 16mm Format Prototypes

### 2.3.2 Halo Free I<sup>2</sup> Technology

The motivation for this technology is the severe deficiency of image intensifier devices with bright source halo and the loss of imaging information due to I<sup>2</sup> halo, especially, in long distance scenes where imaged objects are small as compared to the field of view. This device deficiency becomes more apparent in system application environments with high and dynamic ambient lighting conditions such as Military Operations in Urban Terrain (MOUT). The mechanics of I<sup>2</sup> halo lies with the “bounce” of electrons on the MCP’s solid surface webbing resulting in the formation of the imaged halo as seen in Fig. 6. The size (diameter) of the I<sup>2</sup> halo is solely dependent on the inter element spacing between the photocathode and the input side of the MCP.<sup>6</sup> If the inter element spacing is very small (less than 0.001 inches) then the I<sup>2</sup> halo will also be very small (significantly diminished). Thus, the goal of this technology development effort was to construct a Generation III I<sup>2</sup> tube that had imaging halo performance an order of magnitude reduced as compared to the standard fielded (OMNIBUS IV) Generation III I<sup>2</sup> tube.

- Halo caused by electron scattering within the Photocathode-to-MCP gap

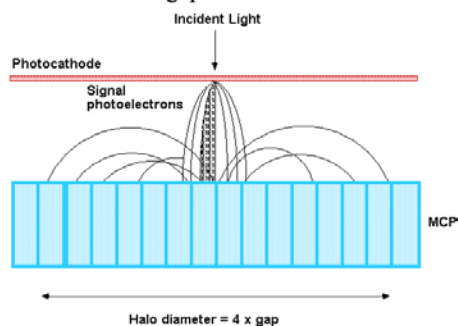


Fig. 6. Halo Effect in Image Intensifier

	Omni IV	Prototype
Halo	0.95*	0.10* mm
S/N	21	25.3
P.C.	1800	1860 $\mu$ a/l
Res.	64	72 lp/mm
Gain	40,000	41,500

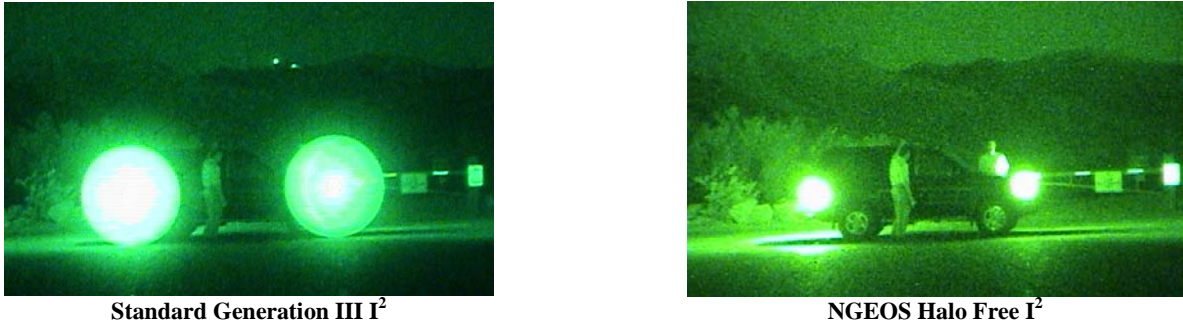
\*Corrected for spot size



Fig. 7. Early Prototype System with NGEOS Halo Free I<sup>2</sup>

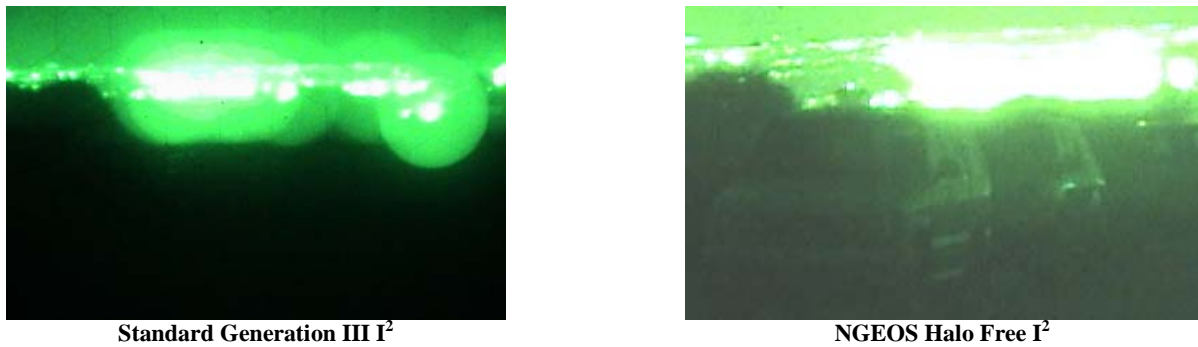
As seen in Fig. 7 with the NGEOS M-983 night vision monocular system, the development effort produced an I<sup>2</sup> device that exceeded the OMNIBUS IV Generation III I<sup>2</sup> performance levels and also had an order of magnitude reduction in halo performance (state-of-the-art performance<sup>6</sup>). It should be noted that the halo measurements test equipment with these improved halo I<sup>2</sup> tube had to be modified with a smaller, 50 micron diameter bright source. This was necessary to

get a clear measurement of the halo performance of this improved I<sup>2</sup> device. Fig. 8 compares NGEOS halo free I<sup>2</sup> technology to standard fielded Generation III I<sup>2</sup> through a NGEOS M983 monocular system. The figure is intensified imaging of persons around a vehicle with bright light sources, and the NGEOS halo free I<sup>2</sup> technology shows that the significantly reduced halo contributes to increased imaging information for I<sup>2</sup> system user.



**Fig. 8.** Comparison of NGEOS Halo Free I<sup>2</sup> to Standard Gen III I<sup>2</sup> in Scene with Vehicle with Bright Lights and Persons

Further illustrating the operational significance of the halo free I<sup>2</sup> technology in Fig. 9, Fig. 9 shows that clear imaging information of vehicles can be obtained in an extremely stringent intensified imaging environment involving urban light sources on a bright horizon.



**Fig. 9.** Imaging of Vehicles under a Bright Horizon with Urban Lights

It should be noted in Fig. 9 that NGEOS “Halo Free” I<sup>2</sup> provides the highest level of image quality with the maximum reduction of image blooming and bright source halo. As noted earlier the NGEOS halo free I<sup>2</sup> and autogated power supply technologies provide significant enhancements to the Unfilmed MCP Generation III I<sup>2</sup> technology. In fact the full combination of unfilmed MCP, autogated power supply, and 16mm halo free I<sup>2</sup> provides the technological foundation for next generation image intensifiers.

### **3. Night Vision Characteristic Performance of Enhanced Generation III I<sup>2</sup> Technologies**

In this section, the characteristic performance of enhanced Generation III I<sup>2</sup> technologies will be presented. Various standard night vision systems will be studied and compared. The following intensified night vision systems will be analyzed,

**18mm I<sup>2</sup> Format**

- AN/PVS-7
- AN/PVS-14
- AN/PVS-17
- AN/PVS-17 4.5X
- AN/PVS-10

**25mm I<sup>2</sup> Format**

- AN/PVS-4
- AN/TVS-5
- AN/PVS-8

Tables 4 and 5 will compare different Generation III I<sup>2</sup> systems defined by Tables 2 and 3 based on system resolution modeling of U.S. Army NVESD Image Intensifier Minimum Resolvable Contrast Model for Direct View Goggles and Rifle Sights Version 3 (March 1999). The modeling calculation was based on USAF 1951 high contrast target patterns. Also, Tables 4 and 5 contain typical imagery for each intensified system to defined target and background at low light level conditions. As seen in Tables 2 and 3, the I<sup>2</sup> tube input parameters for 18mm and 25mm configurations are shown. The I<sup>2</sup> tube inputs are presented for Filmed Generation III, Unfilmed Generation III, and Unfilmed Generation III enhanced I<sup>2</sup> devices for direct comparison in the modeling of the various night vision systems.

**Table 2.** Model Input Parameters for 18mm Format I<sup>2</sup> Tubes







<b>18mm Image Intensifier Format</b>			
	<b>FILMED GEN III</b>	<b>UNFILM GEN III</b>	<b>UNFILM GEN III ENHANCED</b>
Photoresponse	1500	1800	2000
SNR (10 <sup>-5</sup> fc)	19.2:1	26:1	32:1
EBI (10 <sup>-11</sup> photos)	2.5	2.5	2.5
Luminous Gain	40,000	40,000	40,000
Resolution (lp/mm)	64	64	72
MTF % (2.5,7.5,15,25)	92,80,61,38	92,80,61,38	92,80,65,42




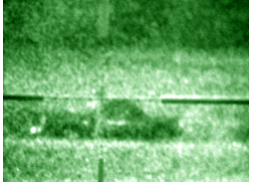
**Table 3.** Model Input Parameters for 25mm Format I<sup>2</sup> Tubes

<b>25mm Image Intensifier Format</b>			
	<b>OMNI V GEN III</b>	<b>OMNI V UNFILM GEN III</b>	<b>UNFILM GEN III ENHANCED</b>
Photoresponse	1200	1600	1800
SNR (10 <sup>-5</sup> fc)	17.5:1	25:1	32:1
EBI (10 <sup>-11</sup> photos)	2.0	2.0	2.0
Luminous Gain	70,000	70,000	70,000
Resolution (lp/mm)	45	45	52
MTF % (2.5,7.5,15,25)	90,70,44,20	90,70,44,20	92,70,52,25

The following table contains night vision system resolution performance modeling results for I<sup>2</sup> night systems with 18mm configured I<sup>2</sup> tubes.

**Table 4.** System Resolution Performance Comparison for Night Vision Systems with 18mm Format I<sup>2</sup> Tubes

<b>18mm Image Intensifier Formatted Night Vision Systems</b>				
Night Vision System	I <sup>2</sup> Tube Type	System Resolution (cycles/mrad)* Light Level (foot-candles)		Typical Image** Low Light
		10 <sup>-2</sup>	10 <sup>-4</sup>	
 AN/PVS-7 (1X)	Filmed Gen III	1.12	0.62	
	Unfilmed Gen III	1.13	0.65	
	Unfilmed Gen III Enhanced	1.17	0.70	
 AN/PVS-14 (1X)	Filmed Gen III	1.14	0.62	 <i>with 3X magnifier</i>
	Unfilmed Gen III	1.16	0.65	
	Unfilmed Gen III Enhanced	1.20	0.70	
 AN/PVS-17 (2.25X)	Filmed Gen III	2.43	1.33	
	Unfilmed Gen III	2.46	1.41	
	Unfilmed Gen III Enhanced	2.55	1.50	







<b>AN/PVS-17 (4.5X)</b> 	Filmed Gen III	4.65	2.41	
	Unfilmed Gen III	4.73	2.54	
	Unfilmed Gen III Enhanced	4.91	2.72	
<b>AN/PVS-10 (8.5X)</b> 	Filmed Gen III	5.85	3.02	
	Unfilmed Gen III	6.01	3.22	
	Unfilmed Gen III Enhanced	6.28	3.48	

\*Based on US Army NVESD Image Intensifier Minimum Resolvable Contrast Model for Direct View Goggles and Rifle Sights Version 3 (March 1999), USAF 1951 High Contrast

\*\*Use of Unfilmed Gen III I<sup>2</sup>; Range for AN/PVS-7 is 100 meters (10<sup>4</sup> fc) to man target, Ranges for AN/PVS-14 and AN/PVS-17s is 550 meters (10<sup>3</sup> fc) to vehicle target, Range for AN/PVS-10 is 600 meters (10<sup>4</sup> fc) to vehicle target

The following table contains night vision system resolution performance modeling results for I<sup>2</sup> night systems with 25mm configured I<sup>2</sup> tubes.

**Table 5. System Resolution Performance Comparison for Night Vision Systems with 25mm Format I<sup>2</sup> Tubes**

<b>25mm Image Intensifier Formatted Night Vision Systems</b>				
<b>Night Vision System</b>	<b>I<sup>2</sup> Tube Type</b>	<b>System Resolution (cycles/mrad)*</b>		<b>Typical Image**</b>
		<b>Light Level (foot-candles)</b>		
		<b>0.1</b>	<b>0.0001</b>	
<b>AN/PVS-4 (3.7X)</b> 	Filmed Gen III	3.64	2.00	
	Unfilmed Gen III	3.71	2.13	
	Unfilmed Gen III Enhanced	4.02	2.29	
<b>AN/TVS-5 (6.2X)</b> 	Filmed Gen III	5.96	3.26	
	Unfilmed Gen III	6.08	3.49	
	Unfilmed Gen III Enhanced	6.56	3.76	
<b>AN/PVS-8 (11.6X)</b> 	Filmed Gen III	9.59	5.07	
	Unfilmed Gen III	8.88	4.93	
	Unfilmed Gen III Enhanced	10.2	5.81	

\*Based on US Army NVESD Image Intensifier Minimum Resolvable Contrast Model for Direct View Goggles and Rifle Sights Version 3 (March 1999), USAF 1951 High Contrast

\*\*Use of Unfilmed Gen III I<sup>2</sup>; Range for AN/PVS-4, AN/TVS-5, and AN/PVS-8 is 400 meters (10<sup>4</sup> fc) to vehicle size target (large sign)

As seen in Tables 4 and 5, Unfilmed MCP I<sup>2</sup> tube technology affords any 18mm or 25mm format night vision system an instant performance improvement upgrade through significant enhancements in system range performance.

#### 4. Ground and Aerial Comparisons of I<sup>2</sup> Technologies

This section show comparisons from photographic still frame and video media of Unfilmed MCP Generation III I<sup>2</sup> and associated enhancement technologies to older I<sup>2</sup> technologies. In Fig. 10, this is a ground comparison of I<sup>2</sup> technologies in a NGEOS AN/PVS-7 night vision goggle with a light level of  $2 \times 10^{-5}$  fc (overcast starlight). As noted in the previous section, the high SNR of the Unfilmed Gen III I<sup>2</sup> system provides in this ground field test the best imaging performance at low light levels as compared to older Generation III I<sup>2</sup> technologies.

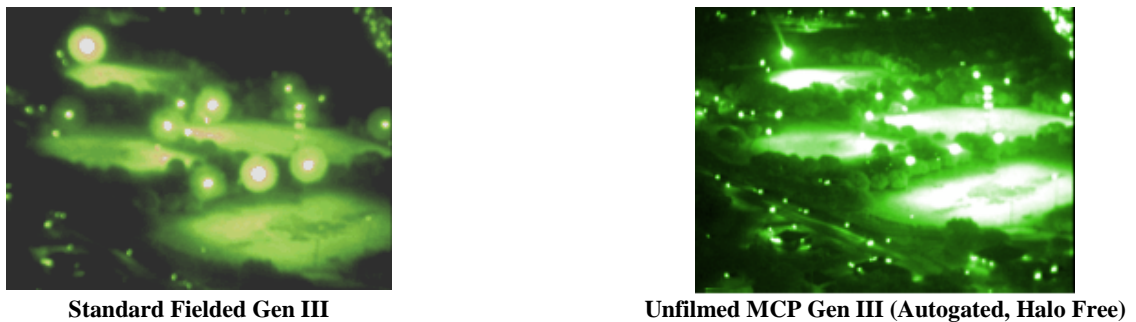


**Fig. 10.** Ground Field Comparison of I<sup>2</sup> Technologies ( $2 \times 10^{-5}$  fc light level)



**Fig. 11.** Aerial Comparison of Autogated Unfilmed Gen III I<sup>2</sup> to Standard Gen III I<sup>2</sup>

Fig. 11 shows a comparison in an AN/AVS-6 night vision goggle system of its left channel having a standard Generation III I<sup>2</sup> tube and its right channel having an autogated, unfilmed MCP Generation III I<sup>2</sup> tube. As seen in Fig. 11, the higher SNR of the unfilmed MCP I<sup>2</sup> tube produces a higher performance image of a low light level scene as compared to the lower SNR found in the standard Generation III I<sup>2</sup> device. This makes autogated, unfilmed MCP I<sup>2</sup> night vision goggles better suited for aviation applications where high performance imaging in low light level scenes is mandatory. It should be noted in this figure that the autogating feature allows for better image control. In this aerial scene case the ability to see the two bridges with bright light source demonstrates this image control.



**Fig. 12.** Aerial Comparison of Halo Free, Autogated Gen III I<sup>2</sup> to Standard Gen III I<sup>2</sup>

Finally, Fig. 12 shows a comparison in an AN/AVS-6 night vision goggle system of its left channel having a standard Generation III I<sup>2</sup> tube and its right channel having a halo free, autogated unfiled MCP Generation III I<sup>2</sup> tube. With the full set of enhancement technologies (Autogating and Halo Free) combined with the base Unfiled MCP I<sup>2</sup> technology, the imaging of difficult, high bright source scenes as in the case of the baseball field complex is easily performed by the combined technologies. NGEOS enhanced Generation III I<sup>2</sup> offers aviation user optimum intensified imaging performance in dynamic lighting conditions as in the case of potential urban landing zones under severe battlefield MOUT conditions.

### 5. Image Fusion (I<sup>2</sup>/IR)-Next Technological Step for Enhanced I<sup>2</sup> Sensors

NGEOS advanced I<sup>2</sup> tube and sensor technologies since 2000 have been supporting the development of manportable, digital image fusion system. This was driven by the 21<sup>st</sup> century military users requirements for low light image intensifier combined digitally with uncooled long wave length infrared (LWIR) sensors in single application packages (weaponsights, driver’s viewers, and headmounted goggle systems). The military tactical motivation for I<sup>2</sup>/IR fusion is as follows,

- “Hot” Target Detection
- Imaging and Detection of NIR Laser Pointers, Aimers, and Designators
- Imaging through Silica Glass Windows
- Battle Field Obscurants (Smoke)

With the significant need for image fusion, NGEOS developed image fusion systems which have demonstrated the tactical advantages noted above as seen in Fig. 13 and 14.



Fig. 13. NGEOS Digital Image Fusion Scene of Soldier with Rifle



Fig. 14. NGEOS Digital Image Fusion Scene of Soldier in Smoke

## 6. Summary and Conclusions

NGEOS advanced I<sup>2</sup> tube technologies as seen in Unfilmed MCP Generation III I<sup>2</sup>, autogated power supply, and halo free I<sup>2</sup> provide both the military and commercial intensified night vision system user the capability to upgrade past, present, and future (21<sup>st</sup> century) intensified night vision systems with state-of-the-art, Generation III I<sup>2</sup> tubes. This enables a form, fit, function solution to enhancing existing systems for both military and commercial users. In all, as seen in Figs. 11-14 the combination of the three NGEOS advanced I<sup>2</sup> technologies provides the intensified night vision user advanced imaging capability for increased situational awareness in dynamically changing environments and the foundation for future integrated electro-optical systems such as digital image fusion systems.

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