Nocturnality

Image Intensifier Tube Selection for Night Vision Systems: Performance, Value, and Usability Method

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Night vision image tube selection for the commercial consumer can be a daunting challenge. Multiple image tube manufacturers, generational structures, technical test specifications, and other factors present the opportunity for buyers to feel overwhelmed and pressured into feeling as though a PhD level of education is needed to make an informed buying decision.

When it comes to selection of an image tube, manufacturer tested specifications are typically the basis for comparison and evaluation, along with (if available) a review of cosmetic imperfections visible within the image tube screen. In the absence of a very detailed understanding of the qualities that commonly tested tube metrics can play in an image tube's capability to recreate a high quality image in a head mounted night vision system, the commonly used evaluation metric known as Figure of Merit (FOM) is often utilized. This two-factor composite 'score' is the industry standard for image tube quality, developed primarily as a tool to rate Generation 3 image tubes in terms of suitability for export by the U.S. government. Unfortunately for the night vision consumer, Figure of Merit is not a well suited method or tool for truly speaking to the performance, usability, and value of an image tube in a wholistic manner.

Figure of Merit makes sense in the context of tube manufacturing and government controls, but it is ineffective as a method of evaluation of image tube use in a ground night vision system where current capabilities have tube center resolution values well in excess of what human vision can detect improvements in in the absence of magnification (such as in the use of a head mounted night vision device).

This paper presents a method for evaluation of image tubes Nocturnality developed internally to better evaluate image tube performance, value, and usability (PVU) with the commercial and professional end user in mind.

The Basis for PVU Evaluation - Signal to Noise Ratio

Evaluating image tubes with the PVU method is done on the basis that the tube's tested signal to noise ratio (SNR) is the primary determining testable metric that speaks to its ability to recreate a detailed image in the widest range of ambient conditions. Although SNR is more important in low to lowest light levels compared to elevated light levels, it is the belief of Nocturnality that low light conditions are the most important for night vision evaluation.

The basis of the PVU methodology is three fold:

- To provide a 'pass/fail' scoring system for image tubes in the context of general civilian and professional use for night vision
- To calculate this score using tube performance metrics that directly affect the tube's ability to create a useable image in a night vision system, and emphasizing the ones that have the most impact on usability
- To take into account other tube characteristics important to the consumer in the overall scoring, including cosmetic defects and properties, and uncommon behaviors that a tube may exhibit based on lighting conditions that can detract from its overall usability

How to Perform a PVU Evaluation

To perform a PVU evaluation, it is necessary to have a tube's manufacturer tested data sheet which records values for Signal to Noise Ratio (SNR), Equivalent Background Illumination (EBI), and Halo values. This methodology is based on accepted U.S. test standards for measuring Halo and EBI levels - for Photonis tubes or other tubes which calculate some of these values in different units of measurement, a conversion is necessary to U.S. standards in order to compare non Gen 3 image tubes.

It is also strongly suggested to properly perform the full evaluation, to be able to visually inspect the image tube within a night vision system to evaluate any condition-driven visual behaviors such as MCP oversaturation (commonly known as ‘tracing’) or phosphor persistence (ghost images, etc).

Manufacturer spot charts are also helpful in performing a PVU evaluation because they provide the proper quantification for size of any visual spot defects, which are taken into account into the method based on their size and location in the viewing area of a tube.

Elements of a PVU Score

The PVU method uses the tube SNR, EBI, and Halo values to create a ‘positive performance’ and ‘negative performance’ numbers specific to each tube. These numbers are weighted based on what Nocturnality believes are the most relevant for image tube performance based on our extensive experience evaluating, using, and building night vision systems. *There is some subjectivity involved in this calculation method*.

Experience has shown to the author of this paper that the large majority of Generation 3, and many competitive tubes from Photonis and other sources, are capable of performing any and all general purpose tasks in the civilian and professional context of ground use for night vision systems, but there are uncommon scenarios where a multitude of factors can result in an image tube that is not advisable for use in the presence of choice. Regardless of this subjectivity, the PVU method still provides a discrete score for a tube - at what score a consumer considers a tube worthy of their investment is still ultimately up to the consumer. We have provided in this resource recommended scoring thresholds, but the method is adaptable for user scrutiny in that regard.

Steps to Perform a PVU Evaluation

The basic steps to perform a PVU evaluation of an image tube are summarized below, with more context and detail in the section following. To calculate a PVU score:

- Subtract 30 from the tested SNR level recorded on the tube's data sheet (i.e. 32.4-30=2.4)
- Divide resulting answer by 10
- Add result from previous step to 4.0 - this gives you the "SNR multiple" value
- Multiply the tested SNR by the resulting SNR multiple from above (i.e. 32.4 x 4.24 = 137.3)

This answer results in the 'positive performance factor' ranging from typically 80 to 160

- Establish 'negative performance factor' by the following equation:
  - (Halo x 3.0) + EBI i.e. (0.8*3.0)+1.5 = 3.9
- Divide the previous 'positive performance factor' by the resulting 'negative performance factor' to establish the 'balanced performance factor' (i.e. 137.3 / 3.9 = 35.2)
- Subtract the original tested SNR value (i.e. 32.4) from the resulting balanced performance factor to present the performance score (i.e. 35.2 - 32.4 = 2.8)

The above steps will generate a performance score (i.e. 2.8). The next steps of a PVU evaluation add or subtract to this performance score based on various usability factors such as tube cosmetics, light behaviors, or uncommon performance factors such as high light resolution, or center resolution below the standard milspec minimum. Although a user could establish their own criteria and point values for usability factors, Nocturnality suggests using the criteria and point values to add or subtract to the base performance score from the table below based on our extensive experience evaluating and using hundreds of tubes over a decade of use:

Criteria	Category	Point Value
Zone 2 blemish .003-.006”	Cosmetic	-1
Zone 2 blemish .006-.009” or larger	Cosmetic	-2
Zone 1 blemish .003” or greater	Cosmetic	-2
MCP oversaturation	Ambient response	-2
Phosphor persistence	Ambient response	-2
Center resolution <64 lp/mm	Uncommon performance result	-2
Excessive autogating noise	Uncommon performance result	-1
No tube cosmetic spots larger than .003”	Cosmetic	+2
Tested high light resolution >36 lp/mm	Uncommon performance result	+2

Additional Context on Calculation Formula

The PVU method works on the idea that a tube’s tested SNR value, as the single largest determinant of overall tube’s ability to generate a quality image in a night vision system, should overcome all of the possible drawbacks that it may otherwise inherently have, such as Halo, high background illumination, cosmetic defects from manufacturing, and other factors.

On this basis, the SNR level is multiplied by a factor which is scaled based on the tested SNR level. A baseline multiple of 4.0 is chosen on the basis of current Generation 3 minimum standards for SNR balanced against statistically common SNR performance values, and the reality that a strong SNR value can often overcome shortcomings of elevated Halo and EBI levels, but a lower SNR value may not in the presence of other negative factors.

Because the EBI level of a tube often can scale with SNR to a degree due to photocathode sensitivity, the actual multiple used in the positive performance factor calculation is adjusted on a sliding statistical scale using the value of 30.0 (which is subtracted from the tested SNR level in first steps). The 30.0 number is chosen as a statistical baseline for when an image tube performance crosses over from 'good' to 'very good' and the EBI level can often sometimes increase.

In the same vein, the Halo value of a tube is also elevated by a multiple, because it is the belief of the author that Halo response of a tube is the most detrimental factor to image tube usability. The factor of 3.0 was chosen as a statistical balance from running dozens of calculations based on real world image tube examples - much over 3.0 and we believe that negative performance factors are over-emphasized compared to their real world implications. Under 3.0, and the SNR level becomes too emphasized and can overcome too many other shortcomings which can have a real impact on users and perceived value relative to other tubes.

Center resolution value is not considered in the PVU calculation for ***ground*** systems specifically because most modern image tubes at the time of this paper's publication have minimum resolution values of 64 line pairs per millimeter, and often are higher. These levels, in the absence of magnification (such as in a clip on optic) are too subjective for most humans to really detect benefit from. Therefore, resolution values are almost entirely excluded from the PVU ground evaluation.

Cosmetic point deductions or additions are purposefully chosen on the basis that, overall, cosmetic defects resulting from modern image tube manufacturing have some bearing on value in the relative sense for general use, but relatively little impact on usability. Therefore, no deductions for "Zone 3" tube defects is suggested, and we have been careful not to overemphasize even Zone 2 defects of any size (while still accounting for them on the basis of relative value).

How to Interpret Image Tube PVU Scores

Resulting PVU evaluation scores typically range from values of -6 to over 15. There is no theoretical limits and the system can scale or be altered as image tube manufacturing continues to evolve. The scale below is how Nocturnality suggests consumers in the night vision world interpret scores of image tubes from a conceptual level to help aid in establishing whether or not they are worthwhile for general use purposes in ground night vision systems.

Score Range	Suggested Interpretation	PASS/FAIL
< -3.0	The image tube has an uncommon combination of negative factors across all areas to be seriously considered for ground use, unless it is available at significantly lower cost	**FAIL**
-3.0 to 3.0	The image tube is within the acceptable range for general performance and has a balance of both positive and negative traits, but overall will perform effectively. This tube is a good value if it is not priced significantly above other options	**PASS**
3.1 to 9.0	The image tube is well above minimally accepted standards for performance and usability and should be highly considered	**PASS**
9.1 to 15.0	The image tube is exceptional in overall performance, usability, and	**PASS**

	value and should be a top candidate for selection for any general purpose or even professional user	
15.1 and above	The image tube is more capable than the overwhelming majority of all image tubes and could realistically command a premium price	**PASS**

Conclusion and Acknowledgements

The PVU method for evaluating image tubes is a holistic method that should aid buyers and users in effectively conceptualizing image tube criteria on a realistic basis. The majority of modern image tubes including Generation 3 and select other options are acceptable for general ground use in a military and civilian context on the basis of current U.S. minimum standards alone, but in some uncommon cases a number of negative factors can result in an image tube which is not acceptable. Sharing and public posting of Generation 3 image tube test sheets is a violation of ITAR.

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