This paper was cleared by ASC: 01-0538 on March 20, 2001

# * Night Vision Goggle Visual Acuity Assessment: Results of an Interagency Test

**H. Lee Task**
Air Force Research Laboratory
Human Effectiveness Directorate
Wright-Patterson AFB, OH 45433-7022

**ABSTRACT**

*There are several parameters that are used to characterize the quality of a night vision goggle (NVG) such as resolution, gain, field-of-view, visual acuity, etc. One of the primary parameters is visual acuity or resolution of the NVG. These two terms are often used interchangeably primarily because of the measurement methods employed. The objectives of this paper are to present: 1) an argument as to why NVG visual acuity and resolution should be considered as distinctly different parameters, 2) descriptions of different methods of measuring visual acuity and resolution, and 3) the results of a blind test by several agencies to measure the resolution of the same two NVGs (four oculars).*

## 1.0 INTRODUCTION

Visual acuity (VA), or more properly, resolution, is probably the most important and frequently stated characteristic of night vision goggles (NVGs). It is often used as the main parameter to compare the quality of one NVG with another. However, even with this level of importance, there is no single, standardized method by which NVG resolution is assessed. The primary objective of this paper is to present several methods to assess NVG resolution that are currently in use by different organizations and compare the results obtained from each. This was accomplished by having two NVGs (a total of four oculars) measured by seven different organizations that are regular participants in the night vision goggle arena. Participants are not identified specifically in this paper but they include organizations within the US Army, US Air Force, US Navy, and industry. It should be noted that it is not an objective of this paper to endorse one measurement method over another; they each have their strengths and weaknesses, which will be discussed. It is a further objective of this paper to provide an indication of the level of reproducibility of results that one can expect due to the different measurement methods and organizations.

## 2.0 RESOLUTION VS VISUAL ACUITY

As indicated earlier, the two terms "resolution" and "visual acuity" are often used interchangeably in characterizing the level of image quality of the NVGs. I would suggest that resolution is primarily a characteristic of the NVG itself (independent of vision) and visual acuity is the resulting visual capability obtained when viewing through an NVG. So the phrase "NVG visual acuity" actually means the latter since NVGs really don't have a visual acuity *per se*. To try to further clarify this subtle, but important, difference it is probably worthwhile to refer to the dictionary definitions of the two terms. The dictionary defines resolution as: "…the process or capability of making distinguishable the individual parts of an object, closely adjacent optical images, or sources of light." The dictionary definition of visual acuity is: "…the relative ability of the visual organ to resolve detail that is usually expressed as the reciprocal of the minimum angular separation, in minutes (of arc), of two lines just resolvable as separate and that forms in the average human eye an angle of one minute." In general, I believe the problem arises from the fact that all methods of assessing the visual quality of the NVGs (in terms of resolution) involve observations and judgements made using the human eye (see following section). When lighting levels and NVG quality are such that the human eye visual acuity far exceeds the resolution capability of the NVGs then the resulting measurements of visual acuity through the NVGs represent the resolution of the NVGs. That is to say the visual acuity obtained viewing through the NVGs is actually also the resolution of the NVGs. The problem occurs when the viewing conditions (light level) or actual resolution of the NVGs are such that they exceed the visual acuity ability of the eye. Under low light level conditions the resolving power of the NVGs is essentially unchanged, but due to the decreased light level and the noise in the NVG the human eye does not have a long enough integration time to perceived the true resolving power of the NVGs. Under this condition one obtains a visual acuity viewing through the NVGs that is primarily the result of limitations in the eye. In this situation one is not so much measuring the capability of the NVG as one is measuring the capability of the particular human eye that made the observations.

* This paper was published in *Proceedings of SPIE Conference No. 4361: Helmet- and Head-Mounted Displays VI*, Orlando, FL, April 16-17, 2001.

Where this distinction between visual acuity and NVG resolution becomes important is in the assessment of NVG capability at low light levels. If one uses the typical test procedure involving observations made by the human eye of a resolution target under low light level, then one is measuring the visual capability of that particular observer as much as they are measuring the capability of the NVG. For this reason, low light "resolution" (really should be visual acuity through NVGs) measurements of NVGs tend to have a higher degree of variability since they are more dependent on the low light level acuity of the particular observer.

For the results presented in this paper only "optimum" light level measurements of NVG resolution were analyzed and included. Some participating organizations made lower light level assessments but the means of characterizing the light level were sufficiently varied as to make it impossible to determine comparability between different organizations with respect to the light levels they used. In any event, the following section presents the different methods and target types that have been used to assess NVG resolution.

## 3.0 MEASUREMENT TECHNIQUES

Each of the seven participating organizations used a slightly different procedure to make NVG resolution measurements of the four oculars. This section describes some of the main procedures but does not necessarily cover each organization's specific procedures. Target types that have been used to make NVG resolution measurements include tumbling "E", Landolt "C", USAF 1951 tri-bar resolution pattern, and square-wave gratings. Procedures have included using a single trained observer or taking the average of three trained observers. Procedures have also involved making subjective judgements (as in whether or not the USAF tri-bars are "resolved" or not) or are completely objective requiring the observer to state the orientation of a target. The following specific procedures are a sample of the NVG resolution procedures that have been or are being used. Please note that the title used for each procedure is not necessarily standardized but was selected to emphasize a particular feature of the procedure.

### 3.1 USAF 1951 Tri-Bar Resolution Chart

The USAF 1951 Tri-Bar Resolution Chart has a very specific format as shown in Figure 1a. This chart is composed of multiple sets of "Tri-Bars" of different sizes oriented both vertically and horizontally. The bars are organized into Groups and Elements such that there are 6 different elements (different sized bars) within each Group. The bars in each Element vary in size by the sixth-root of 2 such that the size of the bars in the first Element of each Group is exactly twice the size of the first element in the following (smaller) Group. This means that each bar pattern is about 12.25% larger than the next smaller bar size. The original USAF 1951 Tri-Bar Chart (Figure 1a) was designed such that the Group 0, Element 1 bar size was exactly 1mm in width. Since that time variations in the original chart have been devised that still use the sixth-root of 2 design concept but are of a different basic size so that they can be used as a large wall chart. Figure 1b shows a picture of such a chart as photographed through one of the NVG oculars used in this study (photo courtesy of Bill McLean, US Army).

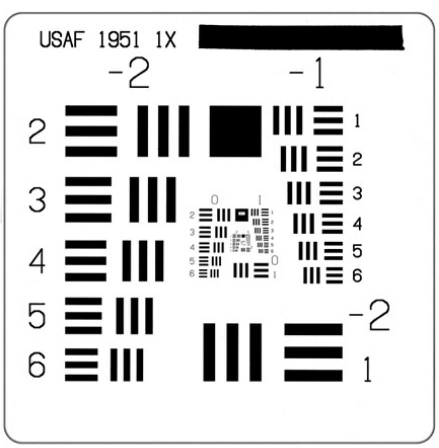

Figure 1a. USAF 1951 Tri-Bar Chart

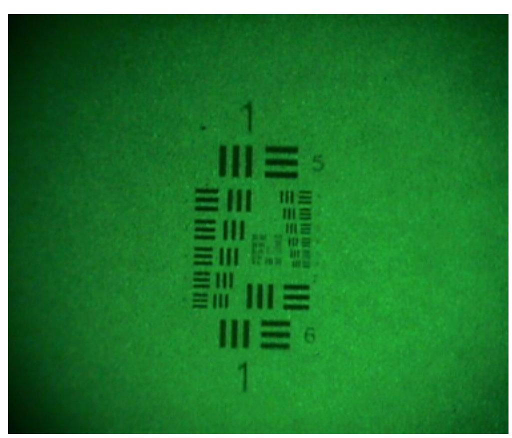
Figure 1b. Variation of USAF 1951 Tri-Bar Chart

The Tri-Bar target sizes can be converted to equivalent Snellen Acuity (SA) values by determining the angular subtense of the bar sizes as measured from the viewing distance. An angular subtense of 1 minute of arc corresponds to a Snellen acuity of 20/20; 2 minutes of arc is 20/40, 3 minutes of arc is 20/60, and so forth. The angular subtense is calculated by taking the arc tangent of the width of the bar divided by the viewing distance. Visual acuity obtained looking through an NVG ocular may be determined by a single observer or by averaging the observations made by a panel of observers (typically 3 observers).

One potential disadvantage of this target type is that the steps between bar sizes are relatively large. For example, if a bar pattern were of a size such that the Snellen acuity was 20/40 then the next larger size would be 20/44.9 and the next smaller size would be 20/35.6 (12.25% differences between sizes). This relatively large "least-count" for this procedure limits the precision with which one can determine the resolution of an NVG ocular; especially if only one observer is used. On the other hand, visual acuity is a relatively difficult parameter to precisely measure, so one could argue that a precision of 12.25% is all that is required.

### 3.2 Hoffman 20/20 Test Set

Prior to flying with NVGs aircrew in the US Air Force are required to pre-flight their NVGs. This includes making adjustments so that the NVGs line up with the individual's eyes and checking visual acuity, usually using the Hoffman ANV-20/20 test set shown in Figure 2. This device provides a collimated image (image at infinity) for the aircrew to focus their objective lenses and to check for visual acuity level. The target pattern used to check visual acuity is shown in the upper left of Figure 2. The pattern consists of 9 target sizes corresponding to 9 different visual acuities. The patterns are patches of square-waves (alternating light and dark bars of equal size) in both vertical and horizontal directions. The legend under the target picture in Figure 2 shows the corresponding VA target sizes, which range from 20/20 to 20/70.

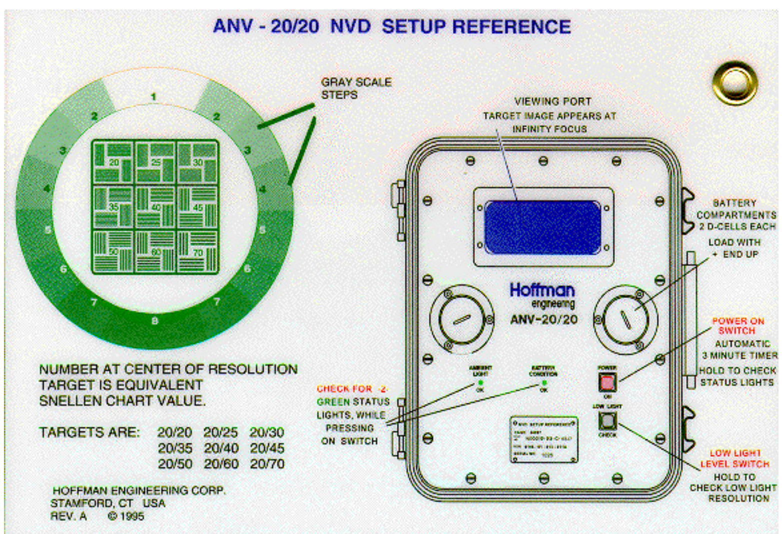

Figure 2. Hoffman ANV-20/20 NVD tester used to pre-flight NVGs (photo courtesy of Hoffman Engineering).

While this device makes an excellent pre-flight instrument, it is not very well suited for making precise measurements of NVG ocular resolution because of the relatively large step sizes. The highest resolution pattern is 20/20 and the next highest is 20/25, which is a large 25% decrease. Its main advantages are that it produces a distant image (using an optical system) within a small space and it can control lighting on the target.

### 3.3. Walk-Back Procedure Using Square-Wave Gratings

This technique was developed as a means to shift from a discontinuous dependent variable to a continuous dependent variable. In other words, one is not limited to specific, quantized levels of visual acuity but, instead, is afforded a complete continuum. The target patterns chosen for this technique are square-wave patches of different spatial frequencies (light and dark bar widths) organized in a pattern shown in Figure 3. A total of 3 charts were used with six grating patch sizes each. The spatial frequency was lower (wider bar widths) on the left side and progressed to higher frequencies (narrower bars) moving to the right. A vertical bar pattern and a horizontal bar pattern were provided for each spatial frequency. These charts were placed a distance of 30 feet from the observer and illuminated with a 2856K light source that could be adjusted. The patches were sized such as to produce whole number Snellen visual acuities at the 30 ft distance such as 20/25 or 20/30. The observer would select the highest spatial frequency grating that he/she could see and inform the experimenter of their selection. Then the observer would slowly step backward until that pattern became a uniform green indicating the NVG could no longer resolve the grating pattern. By using the increased distance, one could calculate the new resolution (Snellen acuity) that corresponded to that particular pattern. For example, if the observer had selected the 20/30 pattern and then walked back 2 feet the resolution of that pattern at the new distance would be 20/[30*(30/32)] = 20/28.1. The grating sizes were selected such that the observer should never have to walk back more than about 3 feet (10%). If they did walk back more than the maximum that meant they should have been able to resolve the next higher resolution pattern at the 30-ft distance. So, if they did walk back past the maximum they were asked to return to the 30 ft distance and look at the next higher spatial frequency patch to see if they could resolve it. The 30 ft distance was selected to minimize possible blur effects caused by focusing the NVGs at 30 feet and then viewing the pattern at distances slightly farther than 30 ft (out to 33 ft). This depth of focus issue is the major disadvantage of this procedure although tests allowing subjects to refocus their NVGs at the longer distances once they had moved back did not produce any noticeably different results.

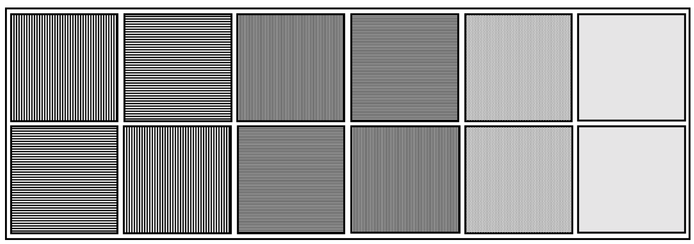

Figure 3. Drawing of the square-wave grating patches used to measure NVG visual acuity using the "walk-back" method.

The major advantage of this technique is to provide a continuum of values that could be obtained for visual acuity. In practice, this procedure normally used 3 trained observers and collected 3 to 5 repeated measures each. The results were then the grand average for all observers and repetitions.

### 3.4 Rotating Grating Technique

A variation of the walk-back technique is the rotating grating method. This technique uses a square-wave grating pattern with the lines running vertically. The grating patch is a rectangle that is about 1.5 times wider than high. This target is placed on a rotating table such that it rotates about an axis that corresponds to the center bar of the pattern. As the pattern is rotated the apparent spatial frequency increases as the view of the pattern is "fore-shortened." The advantage of this technique is that it provides a continuum of values for Snellen acuity. The disadvantage is the same as the walk-back technique in that the focus distance is different for the side of the chart that is closest to the observer compared to the opposite side. However, compared to the walk-back technique, this technique does not require the observer to move and data can be gathered relatively quickly. Initial results indicate the procedure is reasonably repeatable. The base distance (distance from observer to center of the chart) should be 30 feet or greater to minimize the focus disparity between the left and right side of the chart in its rotated position.

### 3.5 Multiple Observations, Multiple Orientation Gratings

Another VA measurement technique to assess NVG oculars uses circular grating patches arranged in rows. In one specific implementation of this procedure the circular target patches were organized into two rows of six gratings each. All of the gratings in a given row were of the same spatial frequency. The gratings were oriented in 4 directions: vertical, horizontal, slanted 45degrees left, and 45 degrees right. Observers were required to state the direction of the grating, making this an objective test. In this particular case, the gratings were designed to be viewed at a distance of 20 feet and the sizes were selected such that each pattern was approximately 12.2 percent larger than the preceding pattern. This corresponds to a size spacing of 0.05 log minimum angle of resolution or 0.05 log MAR. One difficulty with this type of procedure is how to score an individual who gets all of a particular row correct, then misses 2 in the next smaller size row, but then gets all of the next smaller size correct. Some guide must be adopted to determine what score is to be given to an observer who misses one or more orientations in a particular row. For this specific version of this technique a criterion level of achieving 5 of 6 correct orientations in a row was established. The observer was given the Snellen acuity score corresponding to the row in which he/she got 5 of the 6 correct, with a minor modification. If they provided some correct responses on the following row as well, then they were awarded an additional acuity increment of 0.008 log MAR units per correct response. For example, if an observer correctly resolved 5 of 6 patterns on the 20/40.2 (log MAR 0.303) line and resolved 2 patterns on the 20/35.8 line, his/her VA would be scored as 0.303 - 0.016 = 0.287 log MAR or 20/38.7 Snellen). Three observers were used and their average score was recorded as the resultant visual acuity.

## 4.0 RESULTS OF ROUND ROBIN TEST

Two NVGs were selected for this interlaboratory study: one was an older AN/AVS-6 NVG and the other was a more recently produced AN/AVS-9 NVG. The two NVGs were supplied to each organization for testing with the instructions to conduct their normal test procedures for visual acuity (resolution) under two lighting conditions: optimum lighting for best resolution and starlight level lighting. The organizations were directed to measure each ocular (a total of 4 oculars) independently and provide their visual acuity (resolution) results for each of the two lighting levels; a total of 8 numbers. Not all organizations conducted the lower light level measurements and, of those that did, not all of them stated what lighting level was used (in quantitative terms) to simulate the starlight level. For this reason only the "optimum" light level data is included here and analyzed.

Some organizations provided their data in the form of Snellen Acuity values, others submitted their results in terms of cycles per milliradian. In order to make it easy to compare the results between the organizations all data were converted to Snellen Acuity and to cycles per milliradian (Tables 1 and 2). One organization measured the NVGs using two different procedures/devices but their results for the two were identical so only one was used in the analysis. In addition, another organization was the first to measure the NVGs and then measured them again after all of the other organizations had conducted their tests. The results from these two sets of measurements from this organization (using the same procedure both times) were very close so the results from the two were averaged and included in the analysis. A third organization provided raw visual acuity data for two observers (who had significantly different results) so their data was averaged to provide single resolution numbers for their organization. Tables 1 and 2 are a summary of the optimum light level visual acuity data for the seven organizations that participated.

Table 1. Visual acuity results obtained from 7 organizations measuring the same NVGs (results in Snellen acuity-20/xx).

| | **AN/AVS-6** | | **AN/AVS-9** | | **AN/AVS-6** | **AN/AVS-9** |
|---|---|---|---|---|---|---|
| **Lab** | **Left** | **Right** | **Left** | **Right** | **Right-Left** | **Right-Left** |
| A | 33.8 | 35.0 | 26.1 | 26.7 | 1.2 | 0.6 |
| B | 40.0 | 45.0 | 32.0 | 32.0 | 5.0 | 0.0 |
| C | 33.4 | 41.9 | 26.4 | 29.6 | 8.5 | 3.2 |
| D | 31.4 | 31.4 | 23.2 | 23.2 | 0.0 | 0.0 |
| E | 34.7 | 38.2 | 27.5 | 28.6 | 3.5 | 1.1 |
| F | 38.1 | 39.6 | 30.2 | 33.0 | 1.5 | 2.8 |
| G | 40.0 | 39.0 | 31.0 | 32.3 | -1.0 | 1.3 |
| Mean | 35.9 | 38.6 | 28.1 | 29.4 | 2.7 | 1.3 |
| Std | 3.4 | 4.4 | 3.1 | 3.5 | 3.3 | 1.3 |
| t-test p-value for Ho: Mean Difference = 0 | | | | | 0.0743 | 0.0368 |

There are two observations that are apparent from Table 1: 1) the standard deviations for each ocular across organizations are relatively large (on the order of 10-12 percent of mean value) and 2) within each NVG type the determination of which ocular of the two had the better resolution was fairly consistent (right-left columns) although they were not statistically significant at the p=0.01 level (see last row of Table 1). The primary objective of this effort was to determine a reproducibility limit for NVG resolution/visual acuity measurement. The reproducibility limit is defined in ASTM E 691 along with the statistical procedures to calculate it. Basically, if two organizations measure the same NVG ocular there is a 95% probability that their results will differ by no more than the reproducibility limit. This is an indicator of how reproducible the measurement results are and should not be confused with repeatability. Repeatability is an indication of how consistent a single organization's results are when making the same measurement on the same NVG multiple times, whereas the reproducibility limit treats the issue of measurements made by different organizations. Since we collected only one assessment of resolution from each organization for each NVG ocular (at the high light level) we do not have sufficient data to calculate repeatability (which could well be different for the different organizations).

All remaining analyses were accomplished after converting all of the data to resolution in cycles per milliradian (see Table 2) using the conversion equation:

$$\text{Res (c/mrad)} = 34.3775/\text{Snellen (20/xx)} \tag{1}$$

Table 2 lists the NVG ocular resolutions converted to cycles/milliradian (c/mrad). At the bottom of Table 2 is a summary of the Reproducibility Limit (RL) as calculated using ASTM E 691 procedures. The RL was calculated for each type of NVG (AN/AVS-6 and the AN/AVS-9) and for all the oculars as a group. For the levels of resolution of these NVGs, the reproducibility limit was a relatively large 33% (0.35 c/mrad). This means that if we selected a single NVG ocular and randomly selected 2 organizations to measure its high-light-level resolution there is a 95% probability that their answers would agree within 0.35 c/mrad. Another way to look at this is if one randomly selected organization measured the resolution of an NVG ocular and then another (different) randomly selected organization measured a different ocular, then the difference in resolution measurements between the two would have to be greater by 0.35 c/mrad before we would be at least 95% confident that the two oculars were, indeed, different. Note that if we had supplied the two NVG oculars to the same organization then the appropriate confidence parameter would be repeatability and not reproducibility. Although this reproducibility value seems somewhat large it is apparent from the data in Table 2 that there is a wide spread in resolution results between organizations. Looking at the "Right" column of the AN/AVS-9 we see that the highest resolution obtained was 1.48 c/mrad and the lowest was 1.04 c/mrad; a huge 0.41 c/mrad difference!

Table 2. Resolution in cycles/mrad for each lab and ocular. Reproducibility Limits (RL) are given for each goggle separately and across all 4 oculars.

| | **AN/AVS-6** | | **AN/AVS-9** | | **AN/AVS-6** | **AN/AVS-9** |
|---|---|---|---|---|---|---|
| **Lab** | **Left** | **Right** | **Left** | **Right** | **Right-Left** | **Right-Left** |
| A | 1.02 | 0.98 | 1.32 | 1.29 | -0.04 | -0.03 |
| B | 0.86 | 0.76 | 1.07 | 1.07 | -0.10 | 0.00 |
| C | 1.03 | 0.82 | 1.30 | 1.16 | -0.21 | -0.14 |
| D | 1.09 | 1.09 | 1.48 | 1.48 | 0.00 | 0.00 |
| E | 0.99 | 0.90 | 1.25 | 1.20 | -0.09 | -0.05 |
| F | 0.90 | 0.87 | 1.14 | 1.04 | -0.03 | -0.10 |
| G | 0.86 | 0.88 | 1.11 | 1.06 | 0.02 | -0.04 |
| Mean | 0.96 | 0.90 | 1.24 | 1.19 | -0.06 | -0.05 |
| Std | 0.09 | 0.11 | 0.14 | 0.16 | 0.08 | 0.05 |
| RL | 0.28 (30%) | | 0.41 (34%) | | 0.22 | 0.14 |
| (% of Mean) | 0.35 (33%) | | | | 0.18 | |

It is apparent from an inspection of the data in Table 2 that there is some pattern to the variance in resolutions obtained. Specifically, some organizations tended to consistently obtain higher overall resolutions that other organizations. This could be due to the specific type resolution target that was used, the visual capability of the observers, or some other factor. In any event, it is possible to do an analysis to see how much the reproducibility limit could be improved (made smaller) if the differences between organizations were not only consistent but also invariant with time. That is to say, if we were to repeat this effort we would find that the same organizations that tended to obtain higher resolutions in the first effort obtain higher resolutions in the repeat. In order to explore the effects on the reproducibility limit if we could "handicap" labs according to the results of Table 2 we devised a "correction factor" to adjust the scores in Table 2 such that the average for the 4 scores of each lab are the same. This was done by dividing each of the 4 data points for a single lab by a ratio that was calculated by dividing that particular lab's average of the 4 readings by the overall average of the 28 data points. The results of this adjustment are listed in Table 3. The numbers in the second column of Table 3 are the adjustment ratios by which each corresponding row of numbers in Table 2 was divided. Note that the reproducibility limits calculated for Table 3 are greatly reduced from those calculated in Table 2; on the order of 10% instead of 33%.

Table 3. Adjusted Resolution values (cycles\mrad) for each lab and ocular. The resolution values of Table 2 were "adjusted" by dividing each lab's 4 values by an adjustment ratio (Adj. Ratio) that was equal to that lab's average (of the 4 numbers in Table 2) divided by the average of all 28 data points.

| | | AN/AVS-6 | | AN/AVS-9 | | AN/AVS-6 | AN/AVS-9 |
|---|---|---|---|---|---|---|---|
| Lab | Ratio | Left | Right | Left | Right | Right-Left | Right-Left |
| A | 1.07 | 0.95 | 0.92 | 1.23 | 1.20 | -0.03 | -0.03 |
| B | 0.88 | 0.98 | 0.87 | 1.22 | 1.22 | -0.11 | 0.00 |
| C | 1.00 | 1.03 | 0.82 | 1.29 | 1.15 | -0.21 | -0.14 |
| D | 1.20 | 0.91 | 0.91 | 1.23 | 1.23 | 0.00 | 0.00 |
| E | 1.01 | 0.98 | 0.89 | 1.24 | 1.19 | -0.09 | -0.05 |
| F | 0.92 | 0.98 | 0.94 | 1.24 | 1.13 | -0.04 | -0.10 |
| G | 0.91 | 0.94 | 0.97 | 1.22 | 1.17 | 0.02 | -0.05 |
| | Mean | 0.97 | 0.90 | 1.24 | 1.19 | -0.06 | -0.05 |
| | Std | 0.04 | 0.05 | 0.03 | 0.04 | 0.08 | 0.05 |
| | RL | 0.12 (13%) | | 0.09 (7%) | | 0.22 | 0.15 |
| | (% of Mean) | 0.11 (10%) | | | | 0.19 | |

**DISCUSSION/CONCLUSION**

The rather large reproducibility limit (33%) found as a result of analyzing the data of Table 2 is somewhat disturbing but should serve as a major caution flag for any organization making and reporting NVG resolution results. Each of the participating organizations used slightly different procedures to arrive at a resolution number. Some used grating patterns (A and G) and some used tri-bar targets (B through F) as the resolution target. Some used a subjective assessment by observers and some used objective methods. Some used a single observer others used up to 3 observers and averaged the results. All of these differences could contribute to the consistent differences between organizations. However, having looked at the raw data from the 3 observers from our laboratory and the 2 observers from one of the other organizations it is apparent that one of the highest sources of difference is the particular individual(s) that participate in the measurement.

Table 4. Summary of NVG resolution measurement procedures used by the 7 labs.

| Lab | Target | Observers | Procedure | Units |
|---|---|---|---|---|
| A | Grating | 3 | Subjective | Snellen |
| B | Tri-bar | 1 | Subjective | Snellen |
| C | Tri-bar | 1 | Subjective | c/mrad |
| D | Tri-bar | 2 | Subjective | c/mrad |
| E | Tri-bar | 3 | Subjective | Snellen |
| F | Tri-bar | 3 | Subjective | Snellen |
| G | Grating | 3 | Objective | Snellen |

The analysis done for Table 3 on the "adjusted" data provides for the most optimistic reproducibility limit we could expect. The *ex post facto* analysis undoubtedly removed some systematic and some random variance from the data, which resulted in a fairly modest reproducibility limit (about 10%). It is highly unlikely the Adjustment Ratios calculated for each organization would remain exactly the same if we were to conduct this study again. However, there would probably still be a similar general ranking of organizations as to relative level of resolution measured (assuming the same personnel were involved at each location). There may also be some bias due to the type of organization: the highest resolutions were obtained from a vendor of NVGs and the lowest resolutions were obtained from a purchaser of NVGs. The real, practical reproducibility limit probably resides somewhere between the two values calculated from the data in Tables 2 and 3 but we have no way of determining where in between. Suffice it to say that the results of this study serve as a caution to any organization that is involved in NVG resolution measurements that would like to make a statement about the relative quality of a particular NVG compared to one assessed by another organization. The results also indicate that the NVG community should work on standardizing NVG resolution measurement procedures in an effort to improve the reproducibility limit.

## REFERENCES


ASTM E 691-92, (1992) Standard Practice for conducting an interlaboratory study to determine the precision of a test method. American Society for Testing and Materials.

Craig, J.L., Task, H. L., and Filipovich, D. (1997). Development and evaluation of the panoramic night vision goggle. *Proceedings of the Society for Information Display*, Boston, MA, May 12, 1997.

Donohue-Perry, M. M., Task, H. L, & Dixon, S. A. (1994). Visual Acuity vs. Field of View and Light Level for Night Vision Goggles. *Proceedings of SPIE Conference No. 2218 Helmet- and Head-Mounted Displays and Symbology Design Requirements*, Orlando, FL, April, 1994.

Hoffman Engineering ANV 20/20 Night Vision Device Tester, Hoffman Engineering Corp, Stamford, CT.

Levine, Richard R. and Rash, C. E. (1989). Attenuating the luminous output of the AN/PVS-5A night vision goggles and its effects on visual acuity (Report No. USAARL 89-24). US Army Aeromedical Research Laboratory, Fort Rucker, Alabama.

Pinkus, Alan R., Task, H. L., Dixon, Sharon, & Goodyear, Chuck (2000). Reproducibility limits of night vision goggle visual acuity measurements. *SAFE Journal* **30**(1) pp 131-139.

Riegler, J. T., Whiteley, J. D., Task, H. L., & Schueren, J. (1991). *The effect of signal-to-noise ratio on visual acuity through night vision goggles* (Report No. AL-TR-1991-0011). Wright-Patterson AFB, OH: Armstrong Laboratory. (DTIC No. A260579)

Task, H. L., Riegler, Joseph, & Goodyear, Chuck (1999). Effects of laser eye protection and aircraft windscreens on visual acuity through night vision goggles. *Proceedings of the 1999 SAFE Association Symposium,* Atlanta, GA, December 6-8, 1999.

Pinkus, Alan R., Task, H. L., Dixon, Sharon, & Goodyear, Chuck (1999). Reproducibility of night vision goggle visual acuity measurements using Landolt C's. *Proceedings of the 1999 SAFE Association Symposium,* Atlanta, GA, December 6-8, 1999.


## ACKNOWLEDGEMENTS


This research was supported by Night Vision Interface Effects project 71841117 of the Air Force Research Laboratory, Human Effectiveness Directorate at Wright-Patterson Air Force Base, Ohio. The author wishes to thank Chuck Goodyear, of Chuck's Discount Stats, who performed the reproducibility limit analysis in conformance with the ASTM E 691 methodology. In addition, thanks go to Dr. Peter Marasco who helped in nagging the different organizations to get their results in. Last, but not least, thanks go to all of the individuals in the different Air Force, Army, Navy, and Industry organizations that participated in this activity.


## BIOGRAPHY

**H. Lee Task** has been employed as a research scientist for the US Air Force since 1971. He has served as chief scientist for the Armstrong Aerospace Medical Research Laboratory and in March of 1997 was selected as the Senior Scientist for Human-Systems Interface of the new Air Force Research Laboratory at Wright-Patterson AFB, Ohio. He is currently involved in research and development in the areas of helmet-mounted displays, vision through night vision goggles, optical characteristics of aircraft windscreens, vision, and display systems. He has a BS Degree in Physics (Ohio University), MS degrees in Solid State Physics (Purdue, 1971), Optical Sciences (University of Arizona, 1978), and Management of Technology (MIT, 1985) and a Ph.D. in Optical Sciences from the University of Arizona Optical Sciences Center (1978). During his career he has earned 42 patents and has published more than 100 journal articles, proceedings papers, technical reports, and other technical publications.