New Target Acquisition Task for Contemporary Operating Environments: Personnel in MWIR, LWIR and SWIR

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Abstract

Operating environments that US Soldiers and Marines are in have changed, along with the types of tasks that they are required to perform. In addition, the potential imaging sensor options available have increased. These changes make it necessary to examine how these new tasks are affected by waveband and time of day. US Army Research, Development and Engineering Command, Communications Electronics Research Development and Engineering Center, Night Vision and Electronic Sensor Directorate (NVESD), investigated one such task for several wavebands (MWIR, LWIR, Visible, and SWIR) and during both day and night. This task involved identification of nine different personnel targets: US Soldier, US Marine, Eastern-European/Asian Soldier, Urban Insurgent, Rural Insurgent, Hostile Militia, Indigenous Inhabitant, Contract Laborer, and Reporter. These nine distinct targets were made up from three tactically significant categories: Friendly Force, Combatant and Neutral/Non-Combatant. A ten second video was taken of an actor dressed as one of these targets. The actors walk a square pattern, enabling all aspects to be seen in each video clip. Target characteristics were measured and characteristic dimension, target contrast tabulated. A nine-alternative, forced-choice human perception test was performed at NVESD. This test allowed NVESD to quantify the ability of observers to discriminate between personnel targets for each waveband and time of day. The task difficulty criterion, V50, was also calculated allowing for future modeling using the NVESD sensor performance model.

Keywords: V50, SWIR, MWIR, LWIR, Personnel targets, Combatant, TTPm, TTP metric

1. INTRODUCTION

For many years, the target acquisition (TA) task in the US Army and Marine Corps has focused on the detection, recognition, and identification of objects of military interest. These objects ranged from tanks, to trucks, to aircraft. The US Army's Night Vision and Electronic Sensors Directorate (NVESD [1]) developed a suite of target acquisition sensor performance models to methodically predict estimated range performance of different types of imaging sensors. These sensors include image intensifiers, visible and near infrared CCD cameras, as well as short-wave, mid-wave, and long-wave infrared sensors. These models are used to help in the design and evaluation of new imaging sensors by predicting how well they would perform based on the sensor and target specifications.

In today's modern combat zones, the greatest potential threats come from individuals, or groups of individuals, many of whom attack from within civilian populations. Therefore, it is increasingly difficult for Soldiers and Marines to differentiate between friendly, hostile, and non-combative individuals. Because of this, NVESD has adapted its models for this new generation of target acquisition.

In addition to the change in battlefield threats, new technology has allowed for greater versatility in choosing an imaging sensor to complete different target acquisition tasks. SWIR and multi-waveband fused systems are new and promising types of imaging sensors, and when deployed on the battlefield they give the Soldier and Marine an increased ability to detect, recognize, and identify targets. In order to build better sensors and weapon sights for the war fighter, it is necessary to model the expected performance of new sensor designs. To do this, specific target acquisition tasks need to be defined and examined for different wavebands.

NVESD was tasked by the Office of Naval Research (ONR) and US Marine Corps, in support of their Integrated Day/Night Sight Technology (IDNST) program, to model the probability of identifying a set of human targets during day and night, at several ranges, and in a variety of different wavebands (Visible, Image Intensified, SWIR, MWIR, and

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14. ABSTRACT
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LWIR). The task chosen involves the identification of nine different personnel targets. These targets can be defined into three classes: friendly force (US Soldier, US Marine, and Eastern-European/Asian Soldier), combatant (Urban Insurgent, Rural Insurgent, and Hostile Militia), and neutral/non-combatant (Indigenous Inhabitant, Contract Laborer, and Reporter). These targets were chosen because they were considered personnel of interest in battlefield environments.

Imagery of these targets were taken and used to create perception tests designed to determine the task difficulty (V50) **[3]** or identification of each personnel of interest for a given waveband. The task difficulty (V50) is used to model and test the performance of future sensor designs using NVESD's NVThermIP [2] and SSCamIP models. This paper will discuss the methods and results of this task as well as the resulting V50 values from the perception experiment.

Table 1: Description of the personnel targets.

FRIENDLY FORCE	COMBATANT	NEUTRAL / NON-COMBATANT
US Soldier: Clothing: • ACUs & standard outfitting of body armor & ammo pouches Weapons: • M4 (at the ready) • AT-4 (on shoulder)	**"Urban" Insurgent:** Clothing: • BDU pants w/ western shirt • BDU jacket w/ cargo pants Weapons: • AK-47 (at the ready) • RPG (on shoulder)	**Indigenous Inhabitant:** Clothing: • Indigenous clothing (head-dresses) Tools: • Broom (at the ready) • Walking stick (at the ready)
US Marine (Desert and/or Woodland): Clothing: • Woodland • Desert FROG Weapons: • M16A4 (at the ready) • AT-4 (on shoulder)	**"Rural" Insurgent:** Clothing: • Indigenous clothing w/ ammo belt and head wrap • Indigenous clothing w/ BDU jacket (w/out head wrap) Weapons: • AK-47 (at the ready) • RPG (on shoulder)	**Contract Laborer:** Clothing: • Cargo pants w/ jacket & hardhat • Cargo pants w/out jacket & hardhat Tools: • Shovel (at the ready) • Stack of Pipes (on shoulder)
Eastern-European or Asian Soldier/Marine: Clothing: • Woodland BDU • Soviet Uniform Weapons: • AK-47 (at the ready) • RPG (on shoulder)	**Hostile Militia:** Clothing: • All black with body armor • All black w/out body armor Weapons: • AK-47 (at the ready) • RPG (on shoulder)	**Reporter:** Clothing: • Western clothing w/w/o body armor Tools: • Microphone boom (at ready) • Camera (on shoulder)

2. DATA COLLECTION

2.1 Apparent Temperature Calibration

The thermal sensors used for this test were not radiometrically calibrated, therefore thermal reference sources were used to calculate the relative target-to-background temperature differences (ΔTs) from the thermal imagery. Four thermal reference sources were placed near the target and were imaged simultaneously with the target. The temperatures of the references automatically adjust with the ambient temperature; thermal reference temperature readings were captured about every 30 minutes to accurately track the changes. The average grey scale pixel value of each reference was mapped to the recorded reference temperature. Then the "key frame" (one front and side aspect) for each scenario used this map to convert the grey scale values to apparent temperature. The RSS ΔT (root sum squared), Eq 1, was then calculated by taking the average apparent temperature of the target (T_{tgt}) and subtracting it from the average apparent temperature of the background surround the target (T_{Bkg}). The background area is equal to the target area. The standard apparent temperature deviation of the target (σ_{tgt}) is also taken into consideration when the RSS ΔT is calculated.

$$RSS\Delta T = \sqrt{(T_{tgt} - T_{Bkg})^2 + \sigma_{tgt}{}^2} \quad \text{Eq 1}$$

Table 2: A sample of images from visible sensor, showing each activity and variation.

FRIENDLY FORCE	**COMBATANT**	**NEUTRAL / NON-COMBATANT**
US Soldier 	**"Urban" Insurgent** 	**Indigenous Inhabitant** 
US Marine (Desert and/or Woodland) 	**"Rural" Insurgent** 	**Contract Laborer** 
Eastern-European or Asian Soldier/Marine 	**Hostile Militia** 	**Reporter** 

2.2 Targets

The target categories were defined by the US Marine Corps, and represent three tactically significant groups: friendly forces, combatants, and civilians/non-combatants. Each category included three target variations representative of personnel that might be encountered in the current military operating environment. The target categories and characteristics are summarized in Table 1 and illustrated in Table 2.

The targets were imaged at one range. The seven participating actors, all males of average build, were rotated through the target categories in an attempt to neutralize any actor-specific target cues. To assure the target would be imaged from all aspects (front, back, left side, right side), the actors walked in a 'box' pattern, taking approximately two paces per 'side' of the box, thus walking about five feet in each direction. This allowed a ten-second video to capture the full circuit.

Both the US Army and US Marine Corps uniforms were provided by their respective services, and represent current issue US Military uniforms. Clothing and props for the other target categories were chosen from the stock of items maintained by NVESD for use in human activities data collections.

2.3 Environment

Imagery was taken on consecutive days in late July in Maryland on a large grassy field. At night, the moon was almost in its quarter phase and 65% overcast. Nighttime light pollution came from a large city about 30 miles away and a shopping center few miles away. No direct light was shined on the targets at night. The day was 54% overcast and at night there was an electrical storm in the distance.

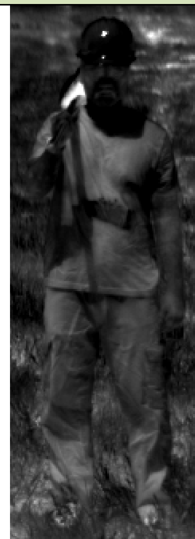
Table 3: Sensor information

Thermal Sensors:	**MWIR**	**LWIR**	
Detector Type	Cooled InSb	Uncooled vanadium oxide (VOx) microbolometer	
Spectral Band	3.6-5.0µm	7.5 -14 µm	
Detector Elements	640 x 512 pixels, 28 µm pitch	640 x 480 pixels, 20.6 µm pitch	
Video output	14 bit uncompressed, 30Hz	Analog RS-170	
Continuous zoom lens	48-342mm focal length	No	
FOV	10.38 x 8.29^{o}	10 x 7.5^{o}	
Reflective Sensors:	**SWIR**	**VISIBLE**	**I^2**
Detector Type	InGaAs Array	Sony ICX414 Progressive Scan CCD	GaAs Photocathode
Spectral Band	0.92 - 1.645 µm (approximate)	Visible	450-900nm
Detector Elements	1280 x 1024 pixels	658 x 492 pixels	1280 x 1024 pixels
Video output	14 bit uncompressed, 60Hz	30Hz, mono, 12 bits per pixel	60Hz, 10 bits per pixel
FOV	40 x 32^{o}	10.6 x 8^{o}	10.8 x 8.6^{o}

2.4 Sensor(s) Information

Five sensors were used for the data collection; two thermal sensors, the MWIR and LWIR, as well as a Raytheon prototype HD SWIR, CCD (visible) and I^2 sensor. The video imagery was collected simultaneously by all sensors, which were co-located as closely together as possible to minimize perspective differences between sensors. Table 3 gives the sensor details.

Table 4: A sample of images from all sensors.

Contract Laborer	LWIR	MWIR	Visible (Day) I2 (Night)	SWIR
Day				
Night				

3. PERCEPTION EXPERIMENT AND MODELING THEORY

Target acquisition models compare the contrast and characteristic dimensions of the target to the system contrast threshold function (CTF). This is done to determine the maximum number of resolvable spatial frequency cycles provided by the sensor on a given "static" target. The number of cycles on target is then compared to an empirically-derived function which estimates probability of task performance. In order to model the identification of personal targets as a function of resolvable cycles on target, the spatial resolution of the imagery needs to be varied. The video images, for each waveband, had their spatial resolution varied by convolving a known Gaussian blur function, to each frame, to limit the maximum spatial frequency content shown to the observer, in a similar way that was reported in Deaver et al [5].

Each test had a set of blur levels, with each value resulting in a different spatial frequency limit for the images in that set [5]. The reduced spatial frequency images were formed by convolving the original high resolution image with a Gaussian blur function, with the standard deviation of the blur function being the blur level value in pixels. Each blur level contained all 9 choices, but not all 32 activities. Half of the activities were shown in each blur level to reduce any learning effects that might occur if all activites where shown for all blur levels and to reduce observer fatigue. All 32 activities were used in each experiment. The blur levels are shown in Table 5. Using the Modulation Transfer Function (MTF) of the known blur kernels, the detector MTF, the modeled noise (SWIR and I2 night)[2], and the measured display MTF, enables a calculation of the spatial frequency cut-off for each set of images used in the analysis.

Table 5: Blur levels used to vary the spatial information for the perception tests.

Waveband	**Blur Levels (Displayed Pixels)**										
LWIR: Day	8	13	19	25	30	34	35	38			
LWIR: Night	8	13	19	25	28	32	33	38			
MWIR: Day	10	15	21	27	32	38					
MWIR: Night	10	15	21	27	32	38					
SWIR: Day	6	12	15	17	23	25	27	31	32	38	45
SWIR: Night	6	11	15	16	20	24	25	27	32	38	45
Visible: Day	15	31	38	45	55	60					
I2: Night	24	31	38	45	50	55					

3.1 Experimental Procedure

To obtain task difficulty (V50) for the task of discriminating personal targets, a nine-alternative, forced-choice (9 AFC) human perception experiment was performed. The experiments measured the probability of correctly identifying the personnel target in dynamic videos and static images, with only one target in the field of view. For the dynamic video images, the target walked around an imaginary box (<10sec). In the static image perception tests, two (front and left side showing) aspects were used, with only one aspect shown for a given selection. The human perception experiment was conducted at NVESD using primarily active duty military personnel. All test participants were trained by a briefing on what the personnel targets looked like for each waveband, with the exception being for the I2 waveband. For the I2, the observers had to pass the visible and SWIR qualification test before taking the I2 perception test. For the qualification test, the observers had to achieve a score of 95% or better. The qualification test used videos of all 9 scenarios (all 32 variations) with a different actor than the actors shown in the experiment the video was collected immediately after the day data collection. In addition, it used the same test interface as the experiment. The qualification test did provide feedback as soon as a selection was made by the observer. Each briefing and qualification test took less than an hour to complete.

The same 9AFC human perception experiment was given to each observer. Each observer had an unlimited time to make a choice on which scenario was played. The video was only played once before fading to black, while the static imagery continued to be displayed until a selection was made. Only after the observer made a selection would the next video or image be displayed. The observer was allowed and encouraged to take breaks. The breaks help avoid eye strain and fatigue.

3.2 Observer Performance

For each scenario and for each blur level the raw probability of identification, P_{ID}, was calculated as the number of correct answers divided by the number of opportunities for each grouping (blur levels). To account for guessing, the raw probability is corrected for chance. This is called the *correction for guessing*[3][4], $P_{corrected,}$ where,

$$P_{Corrected} = \frac{P_{ID} - P_{Chance}}{P_{Expert} - P_{Chance}} \quad \text{Eq 2}$$

The probability of chance success, P_{Chance}, is the lower limit for the rate of correct identification that would be achieved through random guessing. For this experiment, P_{Chance} is equal to 1/9 because there were 9 choices to choose from.

P_{Expert} is the upper limit that one would on average expect an "expert observer" to perform. The P_{Expert} was chosen to be 90%, because that is where observer performance tends to saturate [3][4].

3.3 Modeling Theory

The system CTF is proportional to the CTF of the human eye divided by the system MTF. The system MTF for this experiment was dominated by the MTFs of the blur kernels that were applied to the displayed images and to a lesser extent the detector MTF and the measured display MTF. Though noise was included in the calculation for the system CTF for the SWIR and I2, its affect on the system CTF was minimal. The intersection of the system CTF with the target contrast results in the number of resolvable cycles per mrad on target, ξ_{cut}. In the perception experiment, each blur level corresponds to a different value for ξ_{cut}.

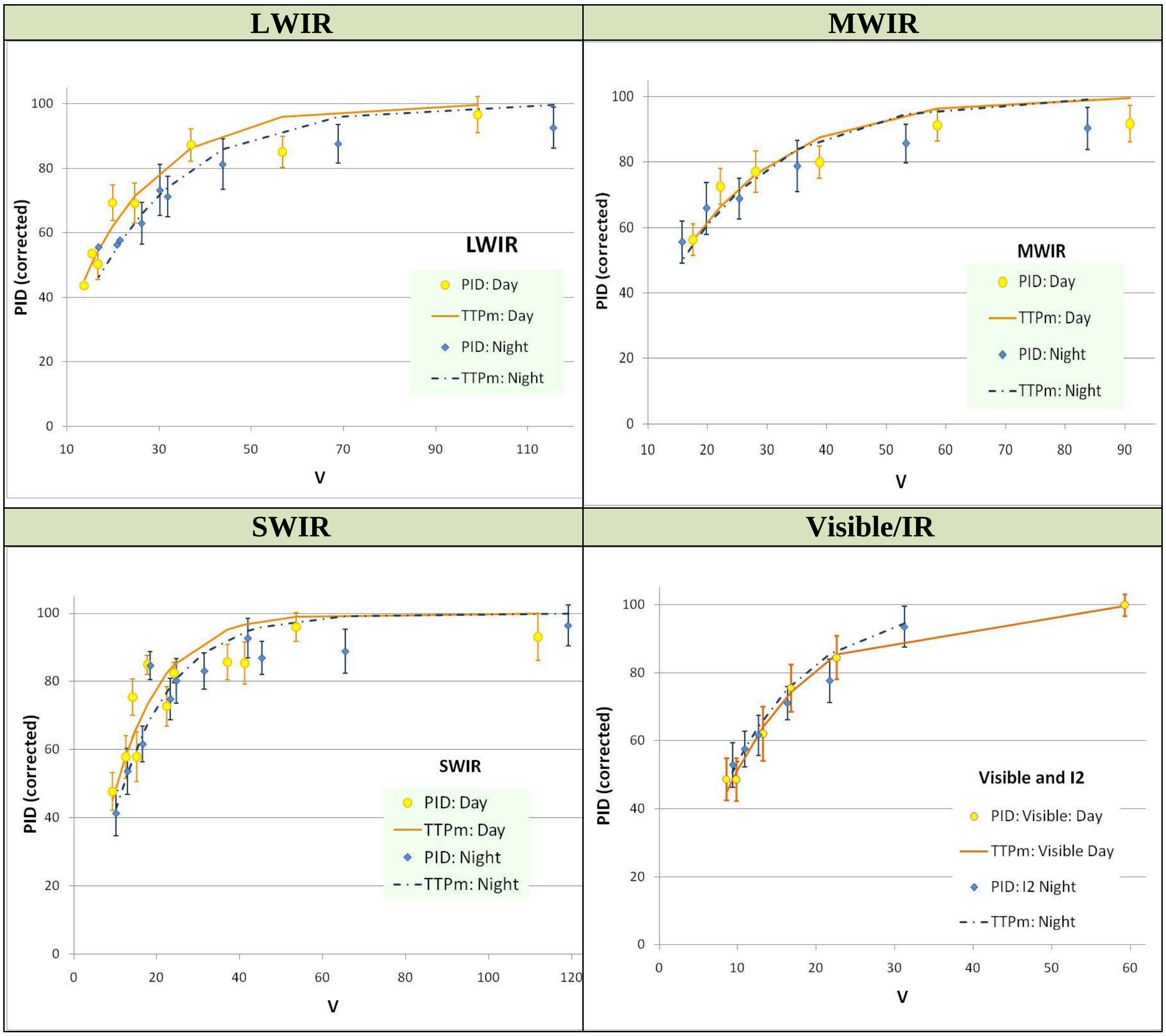


Figure 1: TTP metric fits for all wavebands for both day and night.

NVESD has been moving away from the historical Johnson Metric (N) and its respected N50, to a target acquisition methodology called the Targeting Task Performance (TTP) Metric [3]. This new method is analogous in many ways to the Johnson Metric model; however, instead of a simple calculation of the limiting frequency, N, an integral is performed to capture the benefits of "excess contrast" for spatial frequencies less than ξ_{cut}. The integral is given by,

$$TTP = \int_{\xi_{low}}^{\xi_{cut}} \sqrt{\frac{C}{CTF_{SYSTEM}}} \partial \xi \qquad \text{Eq 3}$$

where C is the Root Sum Squared (RSS) displayed target contrast (**Eq 7**), CTF_{SYSTEM} is the system contrast transfer function, ξ_{low} is the spatial frequency intersection of C and CTF_{SYSTEM}, and ξ_{cut} is the spatial frequency intersection of C and CTF_{SYSTEM} at the high frequency end. The target contrast and system CTF are calculated in the same manner as in the Johnson model, and for this experiment, each blur level corresponds to a unique TTP value. The TTP metric defines V as

$$V = TTP \frac{s}{R} \qquad \text{Eq 4}$$

where s is the characteristic dimention and R is the range the sensor is from the target.

This new method has a slightly different Target Task Performance Function (TTPF) equation form than in the Johnson Metric, which is given by,

$$TTPF = P_{ID}(V) = \frac{(\frac{V}{V_{50}})^{\beta}}{1 + (\frac{V}{V_{50}})^{\beta}} \qquad \text{Eq 5}$$

where the coefficient used in this analysis was β=1.51+0.24(V/V_{50}). Fitting Eq 5 to $P_{Corrected}$ as a function of V, resulted in a V50 model calculated parameter for each task and experiment **[3]**.

In **Figure 1**, the TTPF fits are shown as sold lines for all waveband. The confidence intervals, shown as error bars, is calculated as

$$Confidence\ Interval = mean \pm 1.96 \left(\frac{stdev}{\sqrt{number\ of\ observers}} \right) \qquad \text{Eq 6}$$

where, *stdev* is the standard deviation in the raw P_{ID} of observers for each blur level.

4. CONTRAST

Sensors used in the field are gained and leveled to the observer's preference for the task at hand. If the task is identification, the observer will most likely adjust the contrast to have more grey shades on the target to help differentiate between similar sized objects. In this paper, the goal was to identify personnel targets. All images are contrast stretched for observers' optimization for this task and for each waveband.

Historically, NVESD's field performance prediction has been for vehicles in fields. Recently, NVESD has moved to address issues for the current asymmetric warfare that soldiers are facing, like the task that was investigated for this paper. By taking this departure from identifying vehicles to identifying personal targets, some of the gains and levels that were used to display the images were outside the bounds of the traditional contrast range of NVESD's models, where taking the displayed RSS contrast (**Eq 7**) is normally valid. NVESD is currently working on a new contrast metric (Eq 8) to address high contrast images [6]. The target task difficulty (V50) is calculated using both contrast metrics.

$$RSS = \sqrt{\frac{(\mu_{tgt} - \mu_{bkg})^2 + \sigma_{Tgt}^{\ 2}}{(\mu_{tgt} + \mu_{bkg})^2}} \qquad \text{Eq 7}$$

$$RSS_{adjustment} \equiv \sqrt{\left(\frac{1}{\frac{\mu_{tgt}+\mu_{bkg}}{\left|\mu_{tgt}-\mu_{bkg}\right|}+\frac{1}{M}}\right)^2+\left(\frac{(1-sat)\sigma_{tgt}}{\mu_{tgt}+\mu_{bkg}}\right)^2} \qquad \text{Eq 8}$$

4.1 Experiment Contrast

For all wavebands, contrast was stretched to try to maximize the target's histogram width without overly saturating the weapons or personnel (except when sun reflectance became an issue). In addition, care was taken to try to make the backgrounds for all activities the same to help ensure observers where cueing off the target and not the background. In maximizing the target's histogram's dynamic range, for the MWIR, the background was shifted more toward zero. Having a background near zero is problematic when calculating the RSS displayed contrast (Eq 7). When the background goes to zero the contrast automatically becomes greater or equal to one (Eq 9).

$$RSS(\mu_{bkg}=0) \equiv \sqrt{1+\left(\frac{\sigma_{Tgt}}{\mu_{tgt}}\right)^2} \approx 1+\frac{1}{2}\left(\frac{\sigma_{Tgt}}{\mu_{tgt}}\right)^2 \qquad \text{Eq 9}$$

Table 6: Day and Night background and target histograms for MWIR and LWIR for the Activity: Militant. Red= Target and Blue= Background. The x axis shows the image bit depth was normalized for the histogram between 0 and 1. The y axis is the number of pixels that had that value. For MWIR, the background is saturating at zero and the target is saturating at 1.

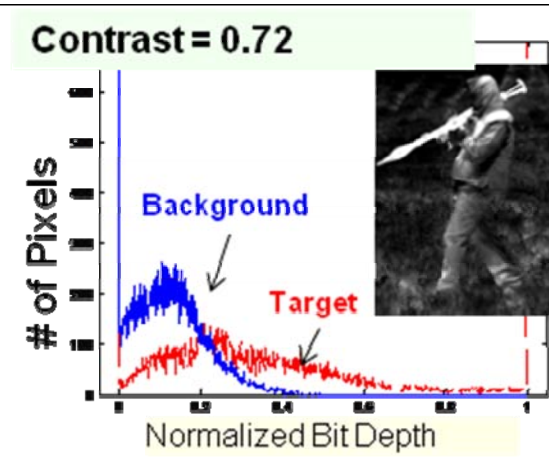
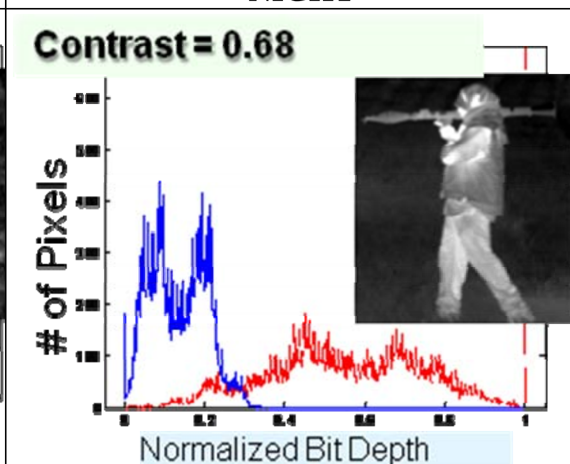
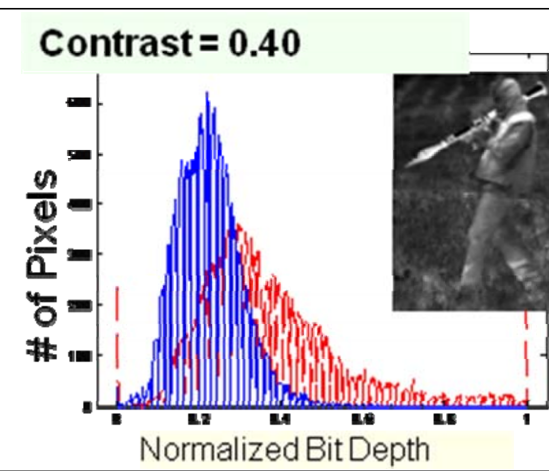
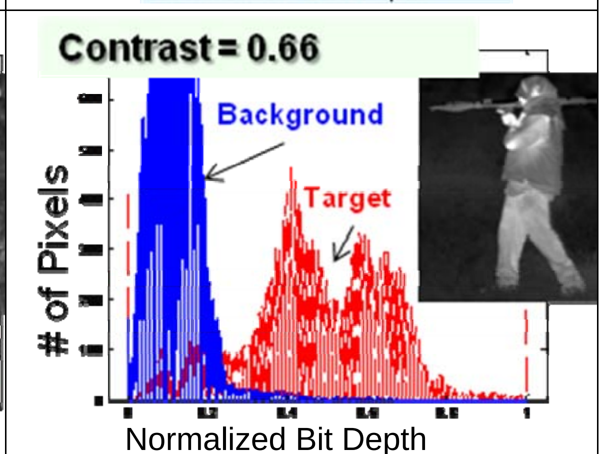
	DAY	NIGHT
MWIR		
LWIR		

Table 6 shows the histograms for both MWIR and LWIR day/night images for a single target. The shape and width for the target's signature are similar between wavebands. In the day, the main difference is that, for the MWIR, the background and target signature is shifted toward zero and sun reflections off metal objects caused some (<5%) saturation of the target at the high end. At night, the LWIR and MWIR have similar strong contrast where the target and background have clear separation. But the MWIR is still higher; this is due to the fact that MWIR's background was made darker to be consistent with the day, which is causing the slightly higher contrast.

The displayed contrast for all wavebands was calculated using both the $RSS_{adjustment}$ and the RSS methods. The results are shown in Table 7. The $RSS_{adjustment's}$ contrast [6] (Eq 8) does an excellent job at capping the contrast when there is a large difference in the target and background. For example, the night time activities for both the MWIR and LWIR saw a reduction in their contrast when the $RSS_{adjustment}$ contrast was used. The reduced contrast produced LWIR and MWIR (night) V50's that were more in line with the day and historical values. But, $RSS_{adjustment}$'s contrast does not help account for large contrast values that are caused by having low target background values.

Table 7: Displayed contrast for all wavebands. Where M=0.1 for $RSS_{adjustment}$.

	Waveband	Display Contrast	
		RSS	$RSS_{adjustment}$
Day	LWIR	0.26	0.24
	MWIR	**0.54**	**0.43**
	SWIR	0.17	0.16
	VISIBLE	**0.47**	**0.33**
Night	**LWIR**	**0.57**	**0.34**
	MWIR	**0.68**	**0.32**
	SWIR	0.19	0.16
	I2	0.33	0.25

Though a better understanding of contrast is underway, the task difficulty values (V50) were calculated using both the RSS and $RSS_{adjustment}$ for the contrast value (Table 8 and Table 9). In addition these results produced range prediction curves that agreed with preliminary validation results. More research is being done to better understand this.

5. RESULTS

V50 calculations for dynamic and static experiments are calculated for multiple wavebands for both the day and the night. These results are shown in Table 8 and Table 9. The bracketed V50's have been calculated using the contrast calculated with the $RSS_{adjustment}$ Contrast Metric. The night V50's for the LWIR and MWIR have RSS contrasts that were outside the boundary where the NVThermIP is valid, but it still produced similar range prediction as the $RSS_{adjustment}$ V50's when contrast was taken into account. The I2 sensor was not used during the day and the visible sensor was not used at night.

Table 8: V50's for dynamic experiment including all wavebands for both the day and the night. The bracketed "()" V50's are the results from using the contrast calculated with the $RSS_{adjustment}$ equation.

DYNAMIC Waveband	DAY: V50 ($RSS_{adjustment}$ V50)	NIGHT: V50 ($RSS_{adjustment}$ V50)	RSSΔT Day (Night)	Char Dim. (m)
LWIR	16	24 (**18**)	2.4 °C (3.7°C)	0.75
MWIR	17 (**15**)	23 (**16**)	2.3 °C (3.3 °C)	0.75
SWIR	11	13		0.75
Visible	12 (**10**)			0.75
I2		11		0.75

Table 9: V50's for static experiment including all wavebands for both the day and the night. The bracketed V50s are the V50 calculation using the contrast calculated with the $RSS_{adjustment}$ Contrast Metric.

STATIC Waveband	**DAY: V50 ($RSS_{adjustment}$ V50)**	**NIGHT: V50 ($RSS_{adjustment}$ V50)**	**RSSΔT Day (Night)**	**Char Dim. (m)**
LWIR	63	56 (42)	2.4 °C (3.7°C)	0.75
SWIR	52 (50)	50 (46)		0.75

NVESD is addressing the fact that NVThermIP assumes a constant eye angle of around 15 degrees when the actual eye angle, especially when range images are displayed, can be much less. This can cause modeling predictions to be different than real observer performance (Teaney, 2008 [7]). Traditionally, V50's were calculated and are calculated here using the image's display angle. The display angle takes into account the size of the image and the distance the observer is from the image to calculate the angle. This display angle does not take into account that the target becomes smaller and thus the eye angle changes when the target moves to farther ranges, which will affect the system CTF.

6. CONCLUSION

The task difficulty (V50) for personnel targets was calculated. For the wavebands and time of day that the contrast was outside of the model's normal contrast range, a new RSS contrast metric was applied and a V50 was calculated with the new contrast value. For some cases, this seemed to help lower the contrast to be within the model limits. In all cases, the V50 calculated from each of these contrast metrics produced quality TTPF fits. Because the contrast, for some values, was outside the model's range of acceptable contrast it is unclear how well the V50's will perform in predicting observer performance in other environments. Promising work is currently being performed to address contrast. For instance, preliminary results show that images from this LWIR night experiment, with RSS contrast adjusted to be 0.30, do not change the performance results of the observers. More definitive work is being planned. In addition, these results are going to be validated with field data. Clearly, more research needs to be done to further understand how target information is being presented to an observer and how the observer is evaluating that information to complete a task, which is currently rolled into the contrast value.

REFERENCES

[1] Army Research Development and Engineering Command, Communications and Electronics Research Development and Engineering Center, Night Vision and Electronics Sensors Directorate (NVESD).

[2] U.S. Army RDECON, CERDEC, NVESD, [Night Vision Thermal and Image Processing (NVThermIP) Model Users Manual, Rev. 9], U.S. Army RDECON, CERDEC, NVESD, (2006).

[3] Vollmerhausen, R., and Jacobs, E., "The targeting task performance (TTP) metric: a new model for predicting target acquisition performance," U.S. Army CERDEC, Fort Belvoir, VA., Technical Report AMSEL-NV-TR-230, pp. 18-42, 47-51 (2006).

[4] Klein, S., A., "Measuring, estimating, and understanding the psychometric function: A commentary," Perception & Psychophysics, 63 (8), 1421-1455 (2001).

[5] Deaver, D. M., Flug, F., Boettcher, E. J., Smith, S. and Miller, B., "Infrared sensor modeling for human activity discrimination tasks in urban and maritime environments," Applied Optics,48 (19), (2009).

[6] Du Bosq, T., and Preece, B., "Improved target signature definition for modeling performance of high-gain saturated imagery," Proc. of SPIE 7662, (2010).

[7] Teaney, B., Fanning, J. "Effect of Image Magnification on Target Acquisition Performance," Proc. of SPIE 6941, 69410P (2008).