TECHNICAL REPORT
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PHOTOSIMULATION CAMOUFLAGE DETECTION TEST

by
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14. ABSTRACT
This report documents the methodology used and the results of a computerized photosimulation evaluation to quantify the military effectiveness of various camouflage patterns across different environments. The evaluation was conducted by the U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) between March 2007 and March 2009. This study extended a digital blending evaluation conducted by NSRDEC in 2006 of two different camouflage patterns in a given environment to multiple environments. The photosimulation evaluation technique used was developed by NSRDEC in collaboration with the Aberdeen Test Center in 2008. The objective was to evaluate the detection performance of camouflage patterns by obtaining visual R_{50} values (range for 50% probability of detection) for a total of 18 standard, foreign and experimental camouflage patterns in various terrain environments under daylight conditions. Probability of detection data were collected from 913 observers. The data clearly show that environment-specific patterns provide the best camouflage, i.e., the lowest probability of detection, in their respective environments. Recommendations for further analysis of the data are included in the report.

15. SUBJECT TERMS

DYES	PATTERNS	CAMOUFLAGE	ARMY PERSONNEL
COLORS	CONTRAST	REFLECTANCE	TARGET DETECTION
FABRICS	BLENDING	DESIGN CRITERIA	INFRARED DETECTION
TERRAIN	DETECTION	COMBAT UNIFORM	SIGNATURE REDUCTION
UNIFORMS	SIGNATURES	VISUAL PERCEPTION	PATTERN RECOGNITION
CAMOUFLAGE PATTERNS		ENVIRONMENTAL CONDITIONS	

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Preface

This report documents the methodology used and the results of a computerized photosimulation evaluation to quantify the military effectiveness of various camouflage patterns across different environments. The evaluation was conducted by the U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) during the period March 2007 – March 2009 under program element number 63001. The objective was to evaluate the detection performance of camouflage patterns by obtaining visual R_{50} values (range for 50% probability of detection) for a total of 18 standard, foreign and experimental camouflage patterns in various terrain environments under daylight conditions. Probability of detection data were collected from 913 observers.

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Mountain Warfare Training Center, VT:

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- Mountain Warfare School students from various units through-out the US

Ft Bliss, TX:

- Warrior Transition Unit
- 6th Brigade Air Defense Artillery

Ft Drum, NY:

- 3-10 General Support Aviation Battalion
- 277 Aviation Support Battalion
- HHC 10th Combat Aviation Brigade
- 2-10 Aviation

Ft Lewis, WA:

- 4-9 Infantry
- 2-23 Infantry
- 1-38 Infantry
- 2-1 Cavalry
- 2-12 Field Artillery

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PHOTOSIMULATION CAMOUFLAGE DETECTION TEST

1.0 Introduction

In 2006 the U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) conducted a digital blending evaluation of two different camouflage patterns: Universal Camouflage Pattern (UCP) and the MultiCam® Pattern[1]. The results, based on 12,000 data points, indicated that MultiCam® performed significantly better than the UCP in most conditions. Though this evaluation determined which pattern blends better in a given environment, further research was necessary to determine the military effectiveness of various camouflage patterns across environments. In 2008, NSRDEC worked with the Aberdeen Test Center to develop a computerized photosimulation evaluation to quantify the effectiveness of various camouflage patterns. The objective was to evaluate the detection performance of camouflage patterns by obtaining visual R_{50} values (range for 50% probability of detection) for a total of 18 standard, foreign and experimental camouflage patterns in various terrain environments under daylight conditions. Probability of detection data were collected from 913 observers. This report documents the methodology used and the results of this evaluation.

2.0 Methodology

Visual camouflage evaluations typically require military observers to participate in multi-day field evaluations. With this approach, there is little control over the environmental conditions (e.g., lighting, shadows, weather), test conditions (e.g., background variation, noise) and observer pool. To better control these factors, the North Atlantic Treaty Organization, Research and Technology Organization (NATO RTO) Task group-SCI-095 developed guidance for photosimulation data collection and analysis[2,3]. This methodology has the advantage of capturing performance under more controlled environmental conditions, as well as bringing field data to the observers rather than bringing the observers to the field. It also has the combined benefits of reducing the costs of the evaluations and increasing the statistical confidence in the results by including more observers. These NATO RTO guidelines were generally followed during the imagery data collection, observer data collection and data analysis portions of this effort. Additional approaches were also employed and are described below.

2.1 Imagery Collection

Imagery was collected in three environments of interest to the US Army: desert, urban and woodland. The desert imagery was collected near the MOUT site at Ft. Irwin, CA., former Ft. Devens, MA was used for the woodland imagery, and the Cassidy MOUT site at Ft. Campbell, KY was used for the urban imagery (Table 1). Three different scenes were used in each environment, as shown in Figures 1 – 3. Images in these figures were taken at 400 m and the arrows indicate the target location in each scene. The three scenes in each environment were selected in an effort to vary either lighting conditions on the target or clutter surrounding the target. However, these scenes represent only a small fraction of the variation that may be encountered in current or future operations.

Imagery was collected at 11 distances for each desert and woodland scene and at 7 distances for each urban scene (Table 2). Due to limitations in the areas surrounding target locations, 400 m was the maximum distance that could be obtained at the urban and woodland sites. This limitation dictated the maximum distance used at the desert site. The minimum imagery distance was 25 m, except in the urban environment where the targets were clearly visible at 125 m due to the nature of that environment. While the goal at each site was to have all patterns undetectable at the longest distance in accordance with the NATO guidelines, this was not always possible, especially for environment–specific patterns used in the "wrong" environment (e.g., a woodland pattern in a desert environment).

Distances were measured using either a construction grade tape measure or a laser range finder. Imagery capture locations were measured and marked prior to imagery collection, which began at approximately 1000 hrs and ended at approximately 1300 hrs. This provided a worst case scenario in terms of pattern effectiveness in bright sunlight. One scene was completed per day, to minimize change in illumination conditions. Imagery data collection for woodland was conducted on two separate occasions, as several patterns (i.e., Desert British, Bulldog, France, and Woodland British) were not available during the first woodland imagery collection. All efforts were made to collect the second set under the same environmental and lighting conditions as were present during the first set.

All imagery was shot using a Nikon D200 digital camera. A focal length of 35 mm was used in order to approximate the resolution that a human observer in the field would see at the same range. All images were taken at three exposure levels (normal exposure, one level up, and one level down). The images from the camera were 2896 pixels high by 1944 pixels wide and decreased slightly to 2400 pixels by 1607 pixels for use in the photosimulation evaluation.

Imagery Collection Locations and Dates

Table 1

Environment	Location	Dates
Woodland	Devens, MA	7 –10 March 2007 15 – 17 July 2008
Desert	Ft Irwin, CA	30 Sept – 5 Oct 2007
Urban	Ft Campbell, KY	17 – 20 March 2008

Environments and Scenes

Table 2

Environment	Scenes			Distance (m)
Woodland (Devens, MA)	Woodland Shade	Woodland Partial Shade	Woodland Bright Sun	25, 50, 75, 100, 125, 150, 175, 200, 250, 300, 400
Urban (Fort Campbell, KY)	Urban Door	Urban Small Building	Urban Corner	125, 150, 175, 200, 250, 300, 400
Desert (Fort Irwin, CA)	Desert Rock	Desert Sage	Desert Sand	25, 50, 75, 100, 125, 150, 175, 200, 250, 300, 400

Sand and Rock

Sage

Desert Scenes

Figure 1

Bright Sun

Partial Shade

Shade

Woodland Scenes

Figure 2

Corner, Small Building and Door

Urban Scenes

Figure 3

All imagery was taken with the target in the center of the image. Furthermore, the target stood facing away from the camera to maximize the amount of pattern visible to the observers and to eliminate any facial cues. The target's standing location was marked to ensure each pattern was evaluated against the exact same background. At a given distance, personnel donning the uniforms quickly rotated through the 18 uniforms. The camera was then moved to the next closest distance, and the process was repeated until the imagery of all uniforms at all distances was captured. Because target detection was the focus of this evaluation, full targets were in the field of view. That is, in the urban scenes, targets were not hidden in windows or doorways, and in the woodland scenes they were not hidden behind brush. Hiding the targets would have decreased the number pixels on a target, and pattern detection would have been confounded. All targets used were approximately the same physical size.

2.2 Observer Data Collection

Prior to the data collection, the observer was given both written and oral instructions followed by a practice set of imagery. Written instructions are included in Appendix A. The imagery used in the practice set consisted of imagery collected at a location not used in the actual photosimulation evaluation. All observer questions were answered before the test began, and discussion between observers was not allowed during the evaluation.

The observer data collection was conducted using four individual stations. Each station consisted of a laptop, mouse and calibrated monitor. The evaluation ran from a laptop that was not accessible to the observer. Observers used only the mouse and monitor. The monitor used was a Samsung SyncMaster 214T, 21.3-inch TFT-PVA. It has a response time of 8ms (G to G) 900:1 contrast ratio, a brightness of 300 cd/m^2, a pixel pitch of 0.270mm, a 1600 x 1200 maximum resolution, a scanning frequency of 30-81 kHz horizontal and 56-75 Hz vertical, and a horizontal/vertical viewing angle of 178/178. Figure 4 shows the typical experimental set-up where the viewing distance was set to 36" to match the magnification of the unaided eye in the field[4]. The calculation for the viewing distance is presented below. This distance was marked on the table with tape, and observers were instructed not to lean in closer than the mark. Each observer was supervised by a test controller (i.e., one test controller for two observers) to ensure proper procedures were followed. Test controllers were situated behind the observer to prevent interference during the photosimulation evaluation.

Viewing eye distance calculation:

$$ED_{lab} = \frac{R_{field} \times HOM_{lab}}{AH_{field}}$$

where:

ED_{lab} = Eye distance in the lab
R_{field} = Range in the field
HOM_{lab} = Height of monitor
AH_{field} = Actual target height in the field

Test Set-up

Figure 4

The program for the photosimulation evaluation was developed by Aberdeen Test Center using Adobe Director, version 8.5. Each run, which was one pattern evaluated over all nine scenes, was set up prior to the observer data collection efforts. To set up a run the test controller programmed the pattern, environment, scene and sector of the image to display (i.e., left, right or center). Although the images were captured with the target in the center, the software allowed the target to be displayed on the left, right or center of the monitor. The targets, as seen by the observers, were always in the same sector (left, right or center) within a series. Presentation of environment, scene and sector was randomized within runs, and two random order presentations were used for each pattern. See Appendix B for the random orders used for each pattern.

Each observer evaluated one pattern over all nine scenes (also referred to as one run). For a given scene, the series of images started at 400 m and moved incrementally closer to the target. The observers were instructed to click on the target in each image throughout the entire series, if and when the target was detected. Upon detection, a “next” button could be used to advance to the next closest image in the series; otherwise, the image automatically advanced to the next closest image after 14 s. All images in a series were viewed, even after initial detection. The software allowed for real-time scoring and recorded, in an Excel file, both time and location of the observer’s click on the target. Figure 5 shows an example of the scoring box used, which was one and a half times the height and width of the target. A click inside the scoring box was recorded as a “hit”. A click outside the scoring box was recorded as a ”miss”. When the observer did not click anywhere on the image, “no response” was recorded. Observers were allowed to click unlimited times on an image; however, only the first click (initial detection) was used as the detection data point.

Scoring Box

Figure 5

2.3 Observers

A total of 885 observers were included in the final analysis. All observers were active duty Army Soldiers, National Guard troops or retired military with theatre experience within the last 5 years. They were drawn from various populations: NSRDEC; Mountain Warfare Training School, VT; Ft. Drum, NY; Ft. Bliss, TX and Ft. Lewis, WA. Table 3 summarizes observer demographic information. Although data were collected from 913 observers, some data were dropped from final analysis due to: incomplete runs, observers having difficulty completing the evaluations or computer and/or equipment issues.

Observer Demographics

Table 3

Location	Number (N)	Mean Age	Male	Female
NSRDEC	26	40	24	2
Mountain Warfare Training Center	47	27	47	0
Ft Bliss	219	33	189	30
Ft Drum	241	30	209	32
Ft Lewis	352	26	352	0
Total	**885**	**30**	**821**	**64**

2.4 Patterns

Eighteen patterns were included in the imagery collection and observer data collection (Figures 6-10). Guidance for pattern selection was given by BG Brown, PEO-Soldier in March 2007. Guidance included patterns of foreign countries, patterns presently available on the commercial market and the UCP. Final pattern selection was controlled by pattern availability. The Woodland and Desert Battle Dress Uniforms (BDU) were not included in this evaluation because, at the time of pattern selection, they were not being worn by the U.S. Army.

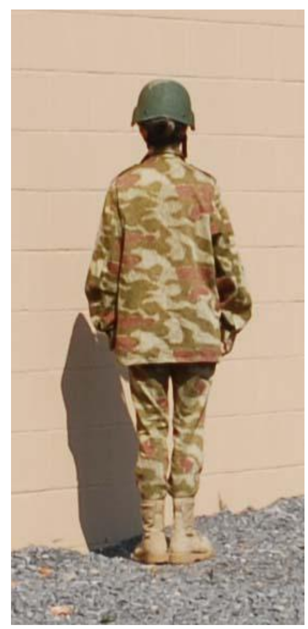
All targets wore desert combat boots and a green Advanced Combat Helmet (ACH). Helmet covers were not worn because of the lack of availability of covers for most patterns. Deployment and training schedules limited the availability of observers during the short data collection period. Therefore, to focus data collection on the patterns of greatest interest, the patterns were prioritized into two tiers. When a complete data set was collected on the Tier 1 patterns, which are annotated in Figures 6-10 with an asterisk, observer data collection then began on the Tier 2 patterns.

Although detection data were collected on 18 patterns, five patterns (i.e., Sweden, Spec4 Woodland, Spec4 Urban, North Korea, and Woodland British) were eliminated from the final data analysis. The two Spec4 patterns were not available for desert image collection; therefore, they did not have a complete data set. Sweden, North Korea and Woodland British were eliminated, due to being the worst performers in two out of the three environments. Their similarity to other woodland patterns was further justification, although it must be noted that detection data are available for further analysis, if desired.

Universal Camouflage Pattern*

Figure 6

			
China	France	Woodland MARPAT*	Iraq
Woodland Patterns			
Figure 7			

			
Desert Brush*	Desert MARPAT*	Desert British	Syria*
Desert Patterns			
Figure 8			

Natural Gear*	Bulldog (Mirage) *	Mossy Oak*	MultiCam® *

Commercial Patterns

Figure 9

Sweden	Spec4 Woodland	Spec4 Urban	North Korea	Woodland British

Patterns Eliminated from Final Analysis

Figure 10

Table 4 shows the number of observers for each pattern and scene. There were approximately 40 observers for each pattern, with three exceptions. Bulldog has fewer data points in the woodland environment because woodland imagery was not available at the onset of the evaluation. MultiCam® and UCP had over 70 responses in most conditions because, initially, these two patterns were the primary patterns of interest. Therefore, the first observer data collection location (Mountain Warfare Training Center) collected data for only the MultiCam® and UCP patterns.

Number of Observers Evaluating Each Pattern by Scene									
Table 4									
	Desert			Urban			Woodland		
	Rock	Sand	Sage	Door	Building	Corner	Bright Sun	Shade	Partial Sun
Desert Brush	48	48	48	48	48	48	48	48	48
Syria	45	38	45	45	45	45	45	45	45
Desert British	49	49	49	49	49	49	46	46	46
Desert MARPAT	45	45	45	45	45	45	45	45	45
MultiCam®	76	77	77	63	76	76	76	77	77
China	47	47	47	47	47	47	47	47	47
Woodland MARPAT	45	45	45	45	45	45	45	45	45
Natural Gear	50	50	50	50	45	50	50	50	50
Mossy Oak	43	38	43	43	43	43	43	43	43
Bulldog	45	45	45	45	45	45	29	29	29
Iraq	44	44	44	44	44	44	44	44	44
France	45	45	45	45	45	45	43	43	43
UCP	70	70	70	63	70	70	70	70	70

3.0 Data Analysis

Statistical Package for the Social Sciences (SPSS)[5] was used to calculate the median R_{50} values using analysis techniques outlined in the NATO guidelines. The initial analysis found unusual patterns in observer responses for approximately 20% of the results. In some cases, there were “hits” at a far distance, followed by one or more closer distances where there were “misses” or “no response”. Figure 11 illustrates examples of response data showing hits, misses and no responses. Green blocks represent hits at a given distance, while the misses and no responses are indicated by the red and yellow blocks, respectively. During observer data collection, some of the computers appeared to run slower than others. It was unclear as to whether data were missing because of computer issues or whether observers were making lucky guesses at the longer distances. In order to address this issue, two alternative detection rules were developed (see Table 5).

Detection Analysis Rules	
Table 5	
Conservative (C)	Move from 25m towards 400m until you reach the maximum distance without a MISS or NO RESPONSE
NATO (Liberal (L))	Move from 400m towards 25m until you reach a HIT
“3 out of 4” Hits (3)	Move a “4 block window” from 400m towards 25m until “3 out of 4” HITS have been achieved then select the furthest HIT achieved; if no “3 out of 4” exists, go with Conservative

The “NATO” rule is labeled liberal because it generates the longest detection distances. The “Conservative” rule resulted in the shortest detection distances, and “3 out of 4” can be described as an intermediate rule. Using these three rules, up to three different detection values were obtained for a given observer. Application of the three rules to each line of observer data is also illustrated in Figure 11 by the use of "L" for "Liberal", "C" for "Conservative" and "3" for "3 out of 4". The distance in meters for each column is noted across the top, while subject identification for each row is noted on the left hand side of the table. A row is one line of data for one observer's detection of a given pattern in one series. To determine the Conservative detection distance for Row A, start from 25 m, and move to the right. The last hit (i.e., green block) before the first miss or no response (i.e., red or yellow block) is the conservative detection distance, 150 m. To determine the Liberal detection distance for the same subject, start at 400 m and move to the left. The first hit, which is at 250 m, is the Liberal detection distance. To determine the "3 of 4" detection distance, move from right to left using a sliding group of four blocks. The first group that has three out of four blocks marked as hits, determines the data area of use. The furthest hit in the block of four is the detection distance for the 3 of 4 rule. For Row A, 250 m is the 3 of 4 detection distance. Miss and no response observer data were treated equally for the analysis.

	25	50	75	100	125	150	175	200	250	300	400
A						C			L 3		
B					C 3				L		
C						C L 3					
D						C		3			L
E						C					L 3
F						C 3				L	
G	C 3							L			
H											C L 3
I	C							L 3			
J	C							L 3			
K	C							L 3			
L		C 3									L
M			C 3								L

(green)	< - Hit
(red)	<- Miss
(yellow)	<- No Response

Sample Observer Data

Figure 11

3.1 Data Adjustments

During the photosimulation evaluation, observers made detections at pre-defined intervals (400, 300, 250, etc.) without the opportunity for detections between intervals (399 through 301, 299 through 251, etc.). Therefore, the observer's detection value is biased towards the lower distance (i.e., the range 399 to 300 is actually represented by 300). It is assumed the actual detection would have taken place somewhere between the actual detection distance and the next highest detection distance. To minimize this bias, a uniform-spacing method is used. The total number of detections in an interval are equally spaced between the distance the detection took place and the next furthest distance value. For example, if four observers detected Pattern A at 50 m, the four detection values would be evenly spaced between 50 and 75 m (i.e., 55 m, 60 m, 65 m and 70 m). The formula below is used to calculate uniform-spacing:

Spacing:

$$(Ra - Rb)/(n+1)$$

Ra = range where "n" detections took place
Rb = next longer range

4.0 Results

4.1 Medians by Rule

The results, when viewed by different rules (Figure 12), show little difference between the Liberal and 3 out of 4 rules. The Conservative rule typically generates the shortest detection distance, while the Liberal and 3 out of 4 generate the longest detection distance. The Conservative rule ignores data with unusual patterns. If there are hits in between misses/no responses, the Conservative rule will ignore those hits and only use the hit at the shortest distance. The results presented in this report are based on the 3 out of 4 rule.

Desert	(b) (2)
Urban	
Woodland	

Medians by Rule

Figure 12

4.2 Medians by Pattern / Environment

Figure 13 shows the individual pattern detection median for 50% probability (R_{50}) of detection by environment. For ease of reading, the graphs are sorted by the top bar graph, desert. The UCP pattern is designated with a red bar for easy reference; desert patterns are tan, commercial patterns are grey, and woodland patterns are green. The patterns dropped from the final analysis as discussed in Section 2.4 appear as white bars. The five dropped patterns are not discussed in the remainder of this report, but data on each pattern are available for additional analysis.

As expected, the desert patterns were detected at shorter distances to the target in the desert environments while the woodland patterns were detected at the shorter distances in the woodland environments. In the urban environment all targets were detected at relatively longer distances.

(b) (2)

Desert — Meters

Urban — Meters

Woodland — Meters

Pattern R_{50} by Environment

Figure 13

The range of detection medians for each environment is stated in Table 6. The range of detection medians is narrower in urban environments and wider in woodland environments.

Range of Medians by Environment	
Table 6	
	Data range
Desert	115 – 400
Urban	130 – 400
Woodland	36 – 400

Figure 14 is a visual depiction of the ranges presented in Table 6 but broken out by the nine scenes. The maximum detection distances in the three urban scenes are all out to 400 m. Patterns were detected at further distances in the woodland sun scene because the lighter patterns were easily detected in this scene. When direct light was decreased or eliminated in the woodland environment, as in the shade and partial sun scenes, detection distances decreased. The desert rock scene was difficult for the observers to detect the targets. The rocks provided enough clutter in the scene to make immediate detection difficult. The desert sage scene generated farther detection distances. This may be due to the target being taller than the sage surrounding him; detection in this scene may have been due to detection of target shape, more than detection of target pattern. The desert sand scene was a low clutter environment where the lighter uniforms camouflaged better with the immediate surroundings.

(b) (2)

Desert

Urban

Woodland

Range of Data for Nine Scenes

Figure 14

4.3 Ranking

The patterns were ranked according to median detection distance and are presented in Table 7. If medians were equal, then the mean was used for ranking. As expected, the desert patterns and woodland patterns performed the best (i.e., lower medians) in their respective environments. By comparison, the desert patterns had poor performance (i.e., higher medians) in the woodland scenes, as did the woodland patterns in the desert scenes. It is noted that a pattern that ranked best in one scene (e.g., desert rock) did not necessarily rank as well in the two remaining scenes.

Ranking of Patterns by Scene

Table 7

	Desert			Urban			Woodland		
	Rock	Sage	Sand	Door	Small Bldg	Corner	Bright Sun	Shade	Partial Shade
	Desert Brush	MultiCam®	Desert British	Desert MARPAT	Desert Brush	Desert Brush	China	China	China
Best	Desert British	Natural Gear	Syria	Natural Gear	Woodland MARPAT	Desert MARPAT	Mossy Oak	Woodland MARPAT	Syria
	Syria	Syria	Desert MARPAT	Desert British	Syria	Desert British	Iraq	French	Iraq
↑	Desert MARPAT	Desert Brush	Desert Brush	MultiCam®	Bulldog	Syria	Woodland MARPAT	Mossy Oak	Woodland MARPAT
	Natural Gear	Desert British	Bulldog	Iraq	Iraq	MultiCam®	French	Iraq	Mossy Oak
	Bulldog	Desert MARPAT	MultiCam®	China	UCP	UCP	Bulldog	Syria	French
	MultiCam®	Mossy Oak	China	Desert Brush	Desert MARPAT	Bulldog	Natural Gear	MultiCam®	Natural Gear
	Woodland MARPAT	Bulldog	Natural Gear	Mossy Oak	MultiCam®	Iraq	Desert British	Desert Brush	MultiCam®
	French	China	UCP	French	Desert British	Natural Gear	Desert MARPAT	Desert MARPAT	Desert Brush
↓	UCP	French	Mossy Oak	UCP	China	French	MultiCam®	Bulldog	Bulldog
	Iraq	Woodland MARPAT	Woodland MARPAT	Syria	Natural Gear	China	Syria	Natural Gear	Desert MARPAT
	Mossy Oak	Iraq	French	Bulldog	Mossy Oak	Mossy Oak	Desert Brush	UCP	Desert British
Worst	China	UCP	Iraq	Woodland MARPAT	French	Woodland MARPAT	UCP	Desert British	UCP

Ranking of Patterns by Environment

Table 8

	Desert	Urban	Woodland
	Desert British	Desert MARPAT	China
Best	Syria	Desert Brush	Woodland MARPAT
	Desert MARPAT	Desert British	Mossy Oak
↑	Desert Brush	MultiCam®	French
	Bulldog	Syria	Iraq
	MultiCam®	Natural Gear	MultiCam®
	Natural Gear	Iraq	Syria
	Mossy Oak	UCP	Bulldog
	UCP	Bulldog	Natural Gear
↓	French	China	Desert Brush
	Woodland MARPAT	Mossy Oak	Desert MARPAT
Worst	China	Woodland MARPAT	UCP
	Iraq	French	Desert British

In order to rank the median detection distance by environment, the data were collapsed over the three scenes within an environment (Table 8). As before, the data shows desert patterns performing well in the desert environment and the woodland patterns performing well in the woodland environment. Of the commercial patterns evaluated, the Mossy Oak pattern performed much like the woodland patterns, possibly due to the dark colors used. Given these environment-specific results, five patterns consistently performed better than UCP – Syria, Desert MARPAT, Desert Brush, MultiCam®, and Natural Gear. Although the performance of the Natural Gear pattern was consistently better than UCP, it is not a viable pattern to consider for possible near-term military use because it does not have military near-infrared properties and the Government has no rights to the pattern. Natural Gear was also the lowest performer of this group of five patterns. Therefore, further discussion is focused on the remaining four uniforms – Desert MARPAT, Desert Brush, MultiCam® and Syria. Syria, although a foreign uniform and not practical for U.S. military use, yielded very favorable results in the environments tested and may be useful in future research on pattern / color effectiveness in multiple environments.

4.4 Results By Pattern

Statistically significant results ($p \leq .05$ based on Mann-Whitney test of significance) for the four patterns that performed consistently better than the UCP are described below. The tables in this section present the same pattern ranks as in Table 7, but they also indicate performance that is statistically better than, equal to and worse than a given pattern, which is highlighted by a bold outline. A highlighted pattern has the possibility of being significantly different from 108 data points (i.e., 12 remaining patterns x 9 scenes). If a pattern appears in a green, grey or tan block, then it has a median detection distance that is significantly worse than the highlighted pattern. If a pattern appears in a white block, then it has a median detection distance that is significantly better than the highlighted pattern. If a pattern appears in a white block but its name is crossed off, then it has a median detection distance that is not significantly different from the highlighted pattern.

4.4.1 UCP: The UCP (Table 9) performed significantly better than 11 of the 108 data points – five patterns in the desert scenes and six patterns in the urban scenes. The performance of the UCP was significantly better in certain desert and urban scenes compared to the darker woodland and commercial patterns. It did not perform significantly better than any pattern in either the woodland environment or the desert sage scene. Sixty-two data points were ranked as significantly better than the UCP – 19 patterns in desert scenes, 10 patterns in urban scenes, and 33 patterns in woodland scenes.

Statistically Significant Results Relative to the UCP

Table 9

Desert			Urban			Woodland		
Rock	Sage	Sand	Door	Small Bldg	Corner	Bright Sun	Shade	Partial Shade
Desert Brush	*MultiCam®*	*Desert British*	*Desert MARPAT*	~~*Desert Brush*~~	*Desert Brush*	*China*	*China*	*China*
Desert British	*Natural Gear*	*Syria*	*Natural Gear*	~~*Woodland MARPAT*~~	*Desert MARPAT*	*Mossy Oak*	*Woodland MARPAT*	*Syria*
Syria	*Syria*	*Desert MARPAT*	*Desert British*	~~*Syria*~~	*Desert British*	*Iraq*	*French*	*Iraq*
Desert MARPAT	*Desert Brush*	*Desert Brush*	*MultiCam®*	~~*Bulldog*~~	*Syria*	*Woodland MARPAT*	*Mossy Oak*	*Woodland MARPAT*
Natural Gear	*Desert British*	*Bulldog*	*Iraq*	~~*Iraq*~~	*MultiCam®*	*French*	*Iraq*	*Mossy Oak*
Bulldog	*Desert MARPAT*	~~*MultiCam®*~~	~~*China*~~	UCP	UCP	*Bulldog*	*Syria*	*French*
MultiCam®	*Mossy Oak*	~~*China*~~	~~*Desert Brush*~~	~~*Desert MARPAT*~~	~~*Bulldog*~~	*Natural Gear*	*MultiCam®*	*Natural Gear*
~~*Woodland MARPAT*~~	~~*Bulldog*~~	~~*Natural Gear*~~	~~*Mossy Oak*~~	~~*MultiCam®*~~	~~*Iraq*~~	*Desert British*	*Desert Brush*	*MultiCam®*
~~*French*~~	~~*China*~~	UCP	~~*French*~~	~~*Desert British*~~	~~*Natural Gear*~~	*Desert MARPAT*	*Desert MARPAT*	*Desert Brush*
UCP	~~*French*~~	~~*Mossy Oak*~~	UCP	~~*China*~~	~~*French*~~	*MultiCam®*	*Bulldog*	*Bulldog*
Iraq	~~*Woodland MARPAT*~~	~~*Woodland MARPAT*~~	~~*Syria*~~	~~*Natural Gear*~~	China	~~*Syria*~~	*Natural Gear*	*Desert MARPAT*
Mossy Oak	~~*Iraq*~~	French	Bulldog	~~*Mossy Oak*~~	Mossy Oak	~~*Desert Brush*~~	UCP	*Desert British*
China	UCP	Iraq	Woodland MARPAT	French	Woodland MARPAT	UCP	~~*Desert British*~~	UCP

Table Key

~~*Strikethrough*~~	Pattern median is not significantly different than highlighted pattern
Italics	Pattern median is significantly better than highlighted pattern
Red	UCP
Green	Woodland Pattern significantly worse than highlighted pattern
Grey	Commercial Pattern significantly worse than highlighted pattern
Lt Brown	Desert Pattern significantly worse than highlighted pattern

4.4.2 Desert Brush: The Desert Brush (Table 10) pattern is an Army developmental pattern. In this evaluation, it performed significantly better than 53 of the 108 data points – 25 patterns in desert scenes, 21 patterns in urban scenes, and seven patterns in woodland scenes. Desert Brush performed significantly better than UCP in six of the nine scenes. Even though 30 patterns performed significantly better than Desert Brush, only one was in a desert scene, while the bulk (i.e., 25 data points) were associated with the woodland environment. Its desert and urban performances were quite favorable.

Statistically Significant Results Relative to the Desert Brush

Table 10

Desert			Urban			Woodland		
Rock	Sage	Sand	Door	Small Bldg	Corner	Bright Sun	Shade	Partial Shade
Desert Brush	~~*MultiCam®*~~	*Desert British*	*Desert MARPAT*	Desert Brush	Desert Brush	*China*	*China*	*China*
~~*Desert British*~~	~~*Natural Gear*~~	~~*Syria*~~	*Natural Gear*	~~*Woodland MARPAT*~~	Desert MARPAT	*Mossy Oak*	*Woodland MARPAT*	*Syria*
Syria	~~*Syria*~~	~~*Desert MARPAT*~~	*Desert British*	~~*Syria*~~	Desert British	*Iraq*	*French*	*Iraq*
Desert MARPAT	Desert Brush	Desert Brush	*MultiCam®*	~~*Bulldog*~~	Syria	*Woodland MARPAT*	*Mossy Oak*	*Woodland MARPAT*
Natural Gear	~~*Desert British*~~	~~*Bulldog*~~	~~*Iraq*~~	~~*Iraq*~~	MultiCam®	*French*	*Iraq*	*Mossy Oak*
Bulldog	~~*Desert MARPAT*~~	MultiCam®	~~*China*~~	~~*UCP*~~	UCP	*Bulldog*	*Syria*	*French*
MultiCam®	~~*Mossy Oak*~~	China	Desert Brush	Desert MARPAT	Bulldog	*Natural Gear*	*MultiCam®*	*Natural Gear*
Woodland MARPAT	Bulldog	Natural Gear	~~*Mossy Oak*~~	MultiCam®	Iraq	*Desert British*	Desert Brush	*MultiCam®*
French	China	UCP	~~*French*~~	Desert British	Natural Gear	*Desert MARPAT*	~~*Desert MARPAT*~~	Desert Brush
UCP	French	Mossy Oak	~~*UCP*~~	China	French	*MultiCam®*	~~*Bulldog*~~	Bulldog
Iraq	Woodland MARPAT	Woodland MARPAT	~~*Syria*~~	Natural Gear	China	~~*Syria*~~	Natural Gear	Desert MARPAT
Mossy Oak	Iraq	Iraq	Bulldog	Mossy Oak	Mossy Oak	Desert Brush	UCP	Desert British
China	UCP	French	Woodland MARPAT	French	Woodland MARPAT	~~*UCP*~~	Desert British	UCP

Table Key

Red Border	Highlighted Pattern of Interest
~~*Strike-Through*~~	Pattern median is not significantly different than highlighted pattern
Italics	Pattern median is significantly better than highlighted pattern
Red	UCP
Green	Woodland Pattern significantly worse than highlighted pattern
Grey	Commercial Pattern significantly worse than highlighted pattern
Lt Brown	Desert Pattern significantly worse than highlighted pattern

4.4.3 Desert MARPAT: This pattern is the present desert combat pattern used by the United States Marine Corps (USMC) (Table 11). It ranked significantly higher than 45 of the 108 data points – 22 patterns in desert scenes, 18 patterns in urban scenes and five patterns in woodland scenes. It ranked best in one of the nine scenes; in eight of the nine scenes it ranked significantly better than the UCP. The one scene where it ranked lower (urban small building) than the UCP, there is no significant difference between their rankings. A total of 29 data points were significantly higher than the Desert MARPAT, with 22 occurring in the woodland environments.

Statistically Significant Results Relative to the Desert MARPAT

Table 11

Desert			Urban			Woodland		
Rock	Sage	Sand	Door	Small Bldg	Corner	Bright Sun	Shade	Partial Shade
Desert Brush	~~*MultiCam®*~~	*Desert British*	Desert MARPAT	*Desert Brush*	*Desert Brush*	*China*	*China*	*China*
Desert British	~~*Natural Gear*~~	~~*Syria*~~	~~*Natural Gear*~~	*Woodland MARPAT*	Desert MARPAT	*Mossy Oak*	*Woodland MARPAT*	*Syria*
~~*Syria*~~	~~*Syria*~~	Desert MARPAT	~~*Desert British*~~	*Syria*	~~*Desert British*~~	*Iraq*	*French*	*Iraq*
Desert MARPAT	~~*Desert Brush*~~	~~*Desert Brush*~~	~~*MultiCam®*~~	~~*Bulldog*~~	~~*Syria*~~	*Woodland MARPAT*	*Mossy Oak*	*Woodland MARPAT*
Natural Gear	~~*Desert British*~~	Bulldog	~~*Iraq*~~	~~*Iraq*~~	MultiCam®	*French*	*Iraq*	*Mossy Oak*
Bulldog	Desert MARPAT	MultiCam®	China	~~*UCP*~~	UCP	*Bulldog*	*Syria*	*French*
MultiCam®	~~*Mossy Oak*~~	China	Desert Brush	Desert MARPAT	Bulldog	~~*Natural Gear*~~	*MultiCam®*	*Natural Gear*
Woodland MARPAT	~~*Bulldog*~~	Natural Gear	Mossy Oak	~~*MultiCam®*~~	Iraq	~~*Desert British*~~	~~*Desert Brush*~~	*MultiCam®*
French	~~*China*~~	UCP	French	~~*Desert British*~~	Natural Gear	Desert MARPAT	Desert MARPAT	*Desert Brush*
UCP	French	Mossy Oak	UCP	~~*China*~~	French	~~*MultiCam®*~~	~~*Bulldog*~~	~~*Bulldog*~~
Iraq	Woodland MARPAT	Woodland MARPAT	Syria	~~*Natural Gear*~~	China	~~*Syria*~~	~~*Natural Gear*~~	Desert MARPAT
Mossy Oak	Iraq	French	Bulldog	~~*Mossy Oak*~~	Mossy Oak	Desert Brush	UCP	~~*Desert British*~~
China	UCP	Iraq	Woodland MARPAT	French	Woodland MARPAT	UCP	Desert British	UCP

Table Key

Red Border	Highlighted Pattern of Interest
~~*Strike-Through*~~	Pattern median is not significantly different than highlighted pattern
Italics	Pattern median is significantly better than highlighted pattern
Red	UCP
Green	Woodland Pattern significantly worse than highlighted pattern
Grey	Commercial Pattern significantly worse than highlighted pattern
Lt Brown	Desert Pattern significantly worse than highlighted pattern

4.4.4 MultiCam®: This pattern (Table 12) is an Army developmental and commercially available pattern. MultiCam® performed significantly better than 44 of the data points – 17 patterns in desert scenes, 15 patterns in urban scenes and 12 patterns in woodland scenes. The consistency of the pattern performance across all three environments indicates a potential to be a viable universal pattern. It performed significantly better than UCP in seven of the nine scenes. With regard to the other two scenes (i.e., desert sand and urban small building), there was no significant difference between MultiCam®'s and UCP's performances. Thirty-four data points are significantly better than MultiCam® – 9 patterns in desert scenes, 5 patterns in urban scenes, and 20 patterns in woodland scenes.

Statistically Significant Results Relative to the MultiCam®

Table 12

Desert			Urban			Woodland		
Rock	Sage	Sand	Door	Small Bldg	Corner	Bright Sun	Shade	Partial Shade
Desert Brush	MultiCam®	*Desert British*	~~Desert MARPAT~~	*Desert Brush*	*Desert Brush*	*China*	*China*	*China*
Desert British	~~Natural Gear~~	*Syria*	~~Natural Gear~~	*Woodland MARPAT*	*Desert MARPAT*	*Mossy Oak*	*Woodland MARPAT*	*Syria*
Syria	~~Syria~~	*Desert MARPAT*	~~Desert British~~	*Syria*	~~Desert British~~	*Iraq*	*French*	*Iraq*
Desert MARPAT	~~Desert Brush~~	*Desert Brush*	MultiCam®	~~Bulldog~~	~~Syria~~	*Woodland MARPAT*	*Mossy Oak*	*Woodland MARPAT*
~~Natural Gear~~	Desert British	*Bulldog*	~~Iraq~~	~~Iraq~~	MultiCam®	*French*	*Iraq*	*Mossy Oak*
~~Bulldog~~	~~Desert MARPAT~~	MultiCam®	~~China~~	~~UCP~~	UCP	*Bulldog*	~~Syria~~	*French*
MultiCam®	Mossy Oak	~~China~~	Desert Brush	~~Desert MARPAT~~	~~Bulldog~~	*Natural Gear*	MultiCam®	*Natural Gear*
~~Woodland MARPAT~~	Bulldog	Natural Gear	Mossy Oak	MultiCam®	Iraq	*Desert British*	Desert Brush	MultiCam®
French	China	~~UCP~~	French	~~Desert British~~	Natural Gear	~~Desert MARPAT~~	Desert MARPAT	~~Desert Brush~~
UCP	French	~~Mossy Oak~~	UCP	~~China~~	French	MultiCam®	Bulldog	Bulldog
Iraq	Woodland MARPAT	Woodland MARPAT	Syria	~~Natural Gear~~	China	~~Syria~~	Natural Gear	Desert MARPAT
Mossy Oak	Iraq	French	Bulldog	~~Mossy Oak~~	Mossy Oak	Desert Brush	UCP	Desert British
China	UCP	Iraq	Woodland MARPAT	French	Woodland MARPAT	UCP	Desert British	UCP

Table Key

Red Border	Highlighted Pattern of Interest
~~Strike-Through~~	Pattern median is not significantly different than highlighted pattern
Italics	Pattern median is significantly better than highlighted pattern
Red	UCP
Green	Woodland Pattern significantly worse than highlighted pattern
Grey	Commercial Pattern significantly worse than highlighted pattern
Lt Brown	Desert Pattern significantly worse than highlighted pattern

4.4.5 Syria: The Syrian pattern (Table 13) performed well in seven of the nine scenes. It performed significantly better than 53 of the 108 data points – 22 patterns in desert scenes, 17 patterns in urban scenes, and 14 patterns in woodland scenes. The consistency of the pattern performance across all three environments indicates a potential to be a viable universal pattern. Only 22 data points performed significantly better than Syria, and over half (i.e., 13 data points) were associated with the woodland environment. Syria performed significantly better than UCP in six out of nine scenes. As for the remaining three scenes, there was no significant difference between Syria's and UCP's performances.

Statistically Significant Results Relative to Syria

Table 13

Desert			Urban			Woodland		
Rock	Sage	Sand	Door	Small Bldg	Corner	Bright Sun	Shade	Patrial Shade
Desert Brush	~~Multicam~~	*Desert British*	*Desert MARPAT*	~~Desert Brush~~	*Desert Brush*	*China*	*China*	*China*
~~Desert British~~	~~Natural Gear~~	Syria	*Natural Gear*	~~Woodland MARPAT~~	~~Desert MARPAT~~	*Mossy Oak*	*Woodland MARPAT*	Syria
Syria	Syria	~~Desert MARPAT~~	*Desert British*	Syria	~~Desert British~~	*Iraq*	*French*	~~Iraq~~
~~Desert MARPAT~~	~~Desert Brush~~	~~Desert Brush~~	*Multicam*	~~Bulldog~~	Syria	*Woodland MARPAT*	*Mossy Oak*	~~Woodland MARPAT~~
Natural Gear	~~Desert British~~	~~Bulldog~~	*Iraq*	~~Iraq~~	~~Multicam~~	*French*	~~Iraq~~	~~Mossy Oak~~
Bulldog	~~Desert MARPAT~~	Multicam	*China*	~~UCP~~	UCP	*Bulldog*	Syria	French
Multicam	~~Mossy Oak~~	China	~~Desert Brush~~	Desert MARPAT	Bulldog	*Natural Gear*	~~Multicam~~	Natural Gear
Woodland MARPAT	~~Bulldog~~	Natural Gear	~~Mossy Oak~~	Multicam	Iraq	*Desert British*	Desert Brush	Multicam
French	China	UCP	~~French~~	Desert British	Natural Gear	~~Desert MARPAT~~	Desert MARPAT	Desert Brush
UCP	French	Mossy Oak	~~UCP~~	China	French	~~Multicam~~	Bulldog	Bulldog
Iraq	Woodland MARPAT	Woodland MARPAT	Syria	Natural Gear	China	Syria	Natural Gear	Desert MARPAT
Mossy Oak	Iraq	Iraq	Bulldog	Mossy Oak	Mossy Oak	~~Desert Brush~~	UCP	Desert British
China	UCP	French	Woodland MARPAT	French	Woodland MARPAT	~~UCP~~	Desert British	UCP

Table Key

Red Border	Highlighted Pattern of Interest
~~St ike-Th ough~~	Pattern median is not significantly different than highlighted pattern
Italics	Pattern median is significantly better than highlighted pattern
Red	UCP
Green	Woodland Pattern significantly worse than highlighted pattern
Grey	Commercial Pattern significantly worse than highlighted pattern
Lt Brown	Desert Pattern significantly worse than highlighted pattern

4.4.6 Performance: Figure 15 shows the detection range improvement in meters and percent, over the UCP, of the four patterns of interest (e.g. MultiCam®, Desert Brush, Desert MARPAT, and Syria) in each of the three environments. It also shows the best performing patterns in each of the environments. Woodland MARPAT is shown as a good U.S. woodland pattern. However, like most woodland patterns, it was relatively ineffective as a universal pattern due to its poor performance in desert and urban environments.

In the desert environment, the MultiCam® pattern median detection point was 16% (b) (2) better than that for the UCP, while Soldiers wearing the Desert Brush and Desert MARPAT patterns can get 28% (b) (2) to 34% (b) (2) closer, respectively, to the observer than those wearing the UCP. The Desert British pattern had the greatest improvement (37% / (b) (2) in the desert environment.

In the urban environment, MultiCam® provided a 16% (b) (2) improvement in median detection distance compared with UCP. Again, Desert Brush and Desert MARPAT performed slightly better than MultiCam®, showing 22% (b) (2) and 24% (b) (2) respectively, improvement over UCP. Desert MARPAT was the best performer in the urban environment.

In the woodland environment, MultiCam® provided a 36% (b) (2) improvement in median detection distance, while Desert MARPAT and Desert Brush provided less advantage, with 16% (b) (2) and 20% (b) (2) improvement, respectively. The darker woodland patterns performed much better, with the China pattern providing a 77% (b) (2) improvement in median detection distance over UCP. Data on all of the woodland patterns are available for further analysis in this specific environment.

Figure 15 shows the trade-off made when looking for a pattern that performs well in all environments. Clearly, desert patterns perform best in desert environments, while woodland patterns perform best in woodland environments. In all environments, the four patterns of interest provided an improvement in detection as compared to UCP. The range of improvement over the three environments was 10-36%.

(b) (2)

Patterns Of Interest				Best Performers by Environment		
UCP	UCP	DM	Desert MARPAT	Desert	DE	Desert British
MC	MultiCam	DB	Desert Brush	Urban	DM	Desert MARPAT
SY	Syria	WM	Woodland MARPAT	Woodland	CH	China

Differences in Median Detection Distances Relative to the UCP

Figure 15

5.0 Discussion

Overall, in the woodland environment, the lighter colored patterns were detected at further distances than the darker patterns. The opposite was found in the desert and urban conditions. These data confirm what is intuitive regarding the performance of environment-specific patterns: woodland patterns perform best in woodland environments, and desert patterns perform best in desert environments.

Although the detection distances for the UCP did not fluctuate tremendously between environments, the performance of other patterns indicated that the visual detection of a Soldier can be enhanced significantly in all environments. The four evaluated patterns of interest (MultiCam®, Desert MARPAT, Desert Brush, Syria) improved the Soldier's visual detectability by decreasing the detection distance by a minimum of 16% in the desert and woodland environments as compared to the target wearing UCP.

The Desert MARPAT is a USMC-specific pattern with Government rights. Visual and near infrared (NIR) standards are in place for this pattern, which is in full-scale production. It performed very well in the desert/urban environments, with marginal performance in the woodland. This pattern did have significant performance improvement over the UCP in eight of the nine scenes evaluated.

The Desert Brush pattern is a Government-owned pattern. It has visual and NIR performance characteristics, but lacks standards for visual, NIR and shortwave infrared (SWIR). To date, it has been printed on nyco and Cordura® fabrics by one printing company. Approximately six months lead time would be needed to get this pattern ready for full-scale production. Desert Brush performed very much on par with Desert MARPAT, performing well in the desert/urban environments and marginally in the woodland. Desert Brush performed better than the UCP in all environments and significantly better in six of the nine scenes evaluated.

The MultiCam® pattern was developed under a U.S. Army development contract and is commercially available. Visual, NIR and SWIR standards have been established on three fabric substrates (i.e., nyco ripstop, 500 denier Cordura®, and Defender™ M - a flame resistant material) printed by a single company. The authors are aware of only one other company that has printed MultiCam® with good visual and NIR properties. MultiCam®'s performance in the desert and urban environments was not as good as the Desert MARPAT and Desert Brush patterns; however, it was significantly better than both patterns in the woodland environment. MultiCam® performed significantly better than the UCP in seven of the nine scenes evaluated.

The Syrian pattern, while not a viable pattern of interest for U.S. Army use, exhibited good performance as a universal pattern. Its performance in both the desert and woodland environments is something to be studied if pattern development is pursued. It performed on par with the best desert pattern and on par with the best universal pattern, i.e., MultiCam®.

As stated earlier, neither the Woodland nor the Desert Battle Dress Uniforms (BDU) were included in this evaluation. At the time patterns were selected for evaluation, neither BDU pattern was being used by the U.S. Army.

6.0 Conclusions and Recommendations

There are many alternatives to consider with regard to camouflage for the U.S. Army. Below are some recommendations on just a few possible courses of action:

1. The data clearly show that environment-specific patterns provide the best camouflage, i.e., lowest probability of detection, in their respective environments. These data clearly indicate that two pattern types, woodland and desert/urban, will provide the best camouflage to the Soldier with missions in these specific environments.

    a. If needed, further analysis of this data set can be done, with specific regard to the woodland environment, to assist with pattern selection or optimization.
    b. Urban environments pose a particular challenge in terms of camouflage development due to the diversity within an urban area and between urban areas.

2. If Army leadership desires, for any number of reasons, to maintain a single, multi-environment camouflage pattern for combat missions, then one must first consider all possible environments that a Soldier can encounter during a mission set. For instance, in present day theaters, Soldiers can manuever from desert mountainous terrain to oasis to urban terrain during a single mission. MultiCam® provides a readily available alternative with good overall performance across all three environments.

    a. It provides a significant reduction in target detectability in all three environments as compared to the UCP. MultiCam® performed better in the woodland environment than the Desert MARPAT and Desert Brush patterns, while those two patterns performed better in the desert environment than MultiCam®.
    b. Specific woodland environment missions may still need to be supplemented with a woodland pattern.

3. Feedback from post combat surveys has indicated Soldier dissatisfaction with the UCP colors, but not with the digital pattern itself. Development of a color-modified UCP would require additional testing to confirm detection and blending effectiveness, and adoption would have the same financial impact discussed in item 4 below.

4. Changing the Army camouflage pattern is a multi-billion dollar issue as it requires a change not only to the uniform, but also to all the clothing and individual equipment items. Options must be carefully weighed regarding this issue. Options include, but are not limited to:

    a. Keeping the UCP as a garrison uniform, while supplementing combat missions with either an improved multi-environment pattern, such as MultiCam®, or environment-specific patterns.

    b. For most personal protective equipment (PPE) and individual equipment items, adopting a solid color that works well with all combat uniform patterns. This is the strategy the USMC has used with their Desert and Woodland MARPAT uniforms and solid coyote-colored PPE and load carriage gear. Potential survivability risks associated with this option have not been characterized by the Army.

5. While development of a new and improved multi-environment pattern is an option, the authors of this report do not believe that significant visual detection performance advances are achievable across all environments over the 10-36% improvement already demonstrated by the four patterns of interest. However, limited incremental improvements may be achievable using current textile technology.

   a. Other aspects that may affect camouflage performance, such as color count, pattern size, color contrast and printing effects, may be considerations in a future pattern development, as these factors potentially impact cost, producibility and durability.

6. Clear requirements are the key to successful implementation of any future camouflage pattern(s). This data set, along with additional studies or specific surveys, may be useful in clearly defining the camouflage pattern requirements.

7. Areas of consideration for future camouflage development include the analysis of mission sets within and across environments and the study of camouflage during the Soldier's movement within operational scenarios verses the static conditions of this study. Also, a thorough review of industry's research and development efforts may introduce novel techniques and advances for military camouflage. For instance, the impact of new industrial capabilities, such as high speed inkjet printing, can be investigated. These capabilities may provide a faster industry response to enable rapidly deployable camouflage specific to a theater of interest.

This document reports research undertaken at the U.S. Army Natick Soldier Research, Development and Engineering Center, Natick, MA, and has been assigned No. NATICK/TR- 09 / 021L in a series of reports approved for publication.

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Appendix A.
Observer Instructions

The ultimate purpose of this work is to improve the effectiveness of land forces through the improvement of camouflage. You will be asked to act as an observer looking for a camouflaged person (target) in a series of pictures. The basic idea of this test is to determine the range at which you detect the target.

You will view 9 different series of pictures. Each series consists of 11 pictures. The first picture in the series is at a far distance from the target; the following pictures gradually bring you closer to the target. Each picture is shown for a maximum of 14 s.

While viewing the pictures, if you detect a target, click on it using the mouse. You will not receive any positive or negative feedback when you click on the target. Once you click on a target, you can then use the next button, located in the lower right hand corner to move quicker through the series. You will continue to view all 11 slides in the series so please click on the target in each slide until the end of the series.

The nine series that you are going to view consist of three woodland, three urban and three desert.

You are looking for a camouflage person, not a vehicle or any type of equipment.

You are looking for ONLY on person in each series.

It is a test of the camouflage patterns, not a test of your personal ability.

Your name will not be recorded on the results.

Do not discuss this test with others.

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Appendix B.
Random Orders for Each Pattern

Run Number	Uniform	Series 1	Series 2	Series 3	Series 4	Series 5	Series 6	Series 7	Series 8	Series 9
1	FFW	D2-2	D3-2	W3-3	W2-1	D1-3	U2-1	W1-3	U3-1	U4-2
2	ACU	D3-2	W1-2	W3-3	W2-1	D1-3	U2-1	W1-3	U3-1	U4-2
3	D. British	U2-2	W3-2	D1-2	U4-1	D2-1	W1-1	U3-3	W2-3	D3-3
4	Bulldog	W2-1	U3-3	D2-2	W1-2	U2-2	D3-3	U4-1	W3-3	D1-3
5	D. MARPAT	D1-2	W3-2	W1-3	U4-1	D3-3	W2-1	U2-3	D2-1	U3-2
6	W. MARPAT	W2-2	U3-2	D2-3	W3-1	U4-3	D3-1	D1-3	U2-1	W1-2
7	D. Brush	U4-2	D2-2	D1-3	W1-1	U3-3	W3-1	D3-3	W2-1	U2-2
8	China	W3-2	U2-2	W2-3	D2-1	W1-3	U3-1	U4-3	D3-1	D1-2
9	French	U4-3	D1-1	W1-2	D2-2	U2-1	W3-3	U3-2	D3-3	W2-1
10	Iraq	U2-2	D3-2	D2-3	D1-1	W2-3	W1-1	U4-3	U3-1	W3-2
11	Mossy Oak	D3-2	U3-2	W2-3	U4-1	W3-2	D1-1	W1-3	U2-1	D2-2
12	N. Korea	U3-2	U2-2	W3-3	W1-1	D2-3	U4-1	D1-3	D3-1	W2-2
13	Sweden	W3-2	D2-2	U4-3	U3-1	W1-3	D3-1	U2-3	W2-1	D1-2
14	Syria	U4-2	W1-2	D3-3	W3-1	U3-3	W2-1	D2-3	D1-1	U2-2
15	W. British	D1-2	U3-3	W1-2	U2-1	D2-1	W2-1	U4-2	D3-3	W3-3
16	FFW (Cloud)	D1-2	U4-2	U1-3	W2-1	D3-3	D2-1	W3-3	W1-1	U3-2
17	ACU (Cloud)	W2-2	W3-2	D1-3	D3-1	U4-3	U1-1	U3-3	D2-1	W1-2
18	N. Gear	D2-2	W2-2	W1-3	U2-1	D1-3	U3-1	D3-3	W3-1	U4-2
19	FFW (Cloud)	U3-2	W1-2	D2-3	D1-1	W2-1	U4-3	D3-1	W3-1	U2-3
20	ACU (Cloud)	W2-2	U4-3	D2-3	W3-1	U3-2	D1-3	W1-1	D3-3	U2-1
21	FFW	W2-2	D3-3	U3-3	D2-1	U2-2	W1-1	D1-2	W3-2	U4-1
22	ACU	U3-3	W1-1	W3-2	D2-1	U2-2	D1-2	W2-1	D3-1	U4-2
23	Spec4W	W3-1	U4-1	U3-2	W1-3	W2-2	U2-1			
24	Bulldog	W1-1	U4-2	D3-2	W2-3	D2-1	W3-2	U3-1	D1-3	U2-3
25	D. MARPAT	U2-1	W1-2	D3-2	W3-1	D1-3	U4-3	D2-2	W2-3	U3-1
26	W. MARPAT	W3-2	D1-1	U3-3	W2-1	U4-2	W1-3	U2-2	D3-3	D2-1
27	D. Brush	W1-2	D2-1	U4-3	W3-2	W2-3	U3-2	D1-1	U2-3	D3-1
28	Mossy Oak	D2-3	U4-2	D1-2	U2-3	W3-1	U3-2	D3-1	W1-1	W2-3
29	Syria	W2-3	D3-1	U3-2	W1-3	D1-2	U4-1	D2-1	U2-3	W3-2
30	N. Gear	D1-2	W3-3	U2-2	U4-1	W2-3	D2-1	W1-2	U3-3	D3-1
31	Spec4U	U4-2	W2-1	W3-2	U2-3	W1-3	U3-1			
32	China	W1-2	D3-3	D2-2	U2-1	W3-3	D1-1	U4-2	W2-1	U3-3
33	N/A									
34	French	W3-2	D2-1	U3-3	W2-2	D1-2	U4-1	D3-3	U2-2	W1-3
35	Iraq	U3-3	W2-1	D2-2	U2-1	W3-3	U4-1	D1-3	W1-2	D3-1
36	N. Korea	D1-2	W1-2	U2-1	D3-3	W3-1	U3-3	D2-1	W2-3	U4-2
37	Sweden	D3-2	U3-3	W2-2	D2-1	W3-3	U4-2	D1-3	W1-1	U2-1
38	W. British	W3-1	D3-2	D1-1	W2-2	U2-2	U4-3	D2-3	W1-3	U3-1
39	Spec4W	U3-1	W3-2	W1-1	U4-2	U2-3	W2-3			
40	D. British	D1-3	W1-2	U4-3	W2-1	D3-2	U2-1	W3-3	D2-1	U3-2
41	Spec4U	W3-1	U2-2	W1-2	U3-3	W2-3	U4-1			