(2)

GUIDE TO

# CAMOUFLAGE

FOR

# DEVELOPERS



VOLUME I

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Prepared for

COUNTERSURVEILLANCE AND DECEPTION DIVISION
U.S. ARMY BELVOIR RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
TROOP SUPPORT COMMAND
ARMY MATERIAL COMMAND



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UNDER PROJECT NUMBER 170-002

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MR. DEVELOPER:

WHAT WILL DEFEAT YOUR SYSTEM?

REMEMBER: BEFORE THE ENEMY FIRES AT YOUR SYSTEM, HE MUST FIND IT.



WILL YOUR SYSTEM HAVE:

REFLECTIVE SURFACES?
UNINTENDED RADIO FREQUENCY EMISSIONS?
DETECTABLE HEAT SOURCES?
MUZZLE FLASH?
VISUAL IDENTIFICATION?
ACOUSTIC SIGNATURE?

THIS BOOK HELPS TO PREVENT DEFEAT AT STAGE ONE.

USE IT!

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# CONSERVE THE FORCE

# THROUGH CAMOUFLAGE

## SECTION 1

## INTRODUCTION

### 1.1 GENERAL

Development of new materiel for the Army is widely understood to be a complex undertaking. Despite the hurdles along the way, the end goal is to produce an array of tools which the field commander can use to achieve battlefield success. A key ingredient of the materiel provided to the field must be inherent survivability. The combat developer and the materiel developer must examine many alternatives in the process of enhancing the survivability of a system under development. Camouflage is one of the survivability enhancements that must be considered during the development process. In fact, AMC/TRADOC Pam 70-2 places responsibility for including camouflage of equipment among the tasks to be accomplished by developers of an item of equipment. This Guide is provided to assist developers in the execution of their responsibility.

### 1.2 PURPOSE AND SCOPE

#### 1.2.1 Purpose.

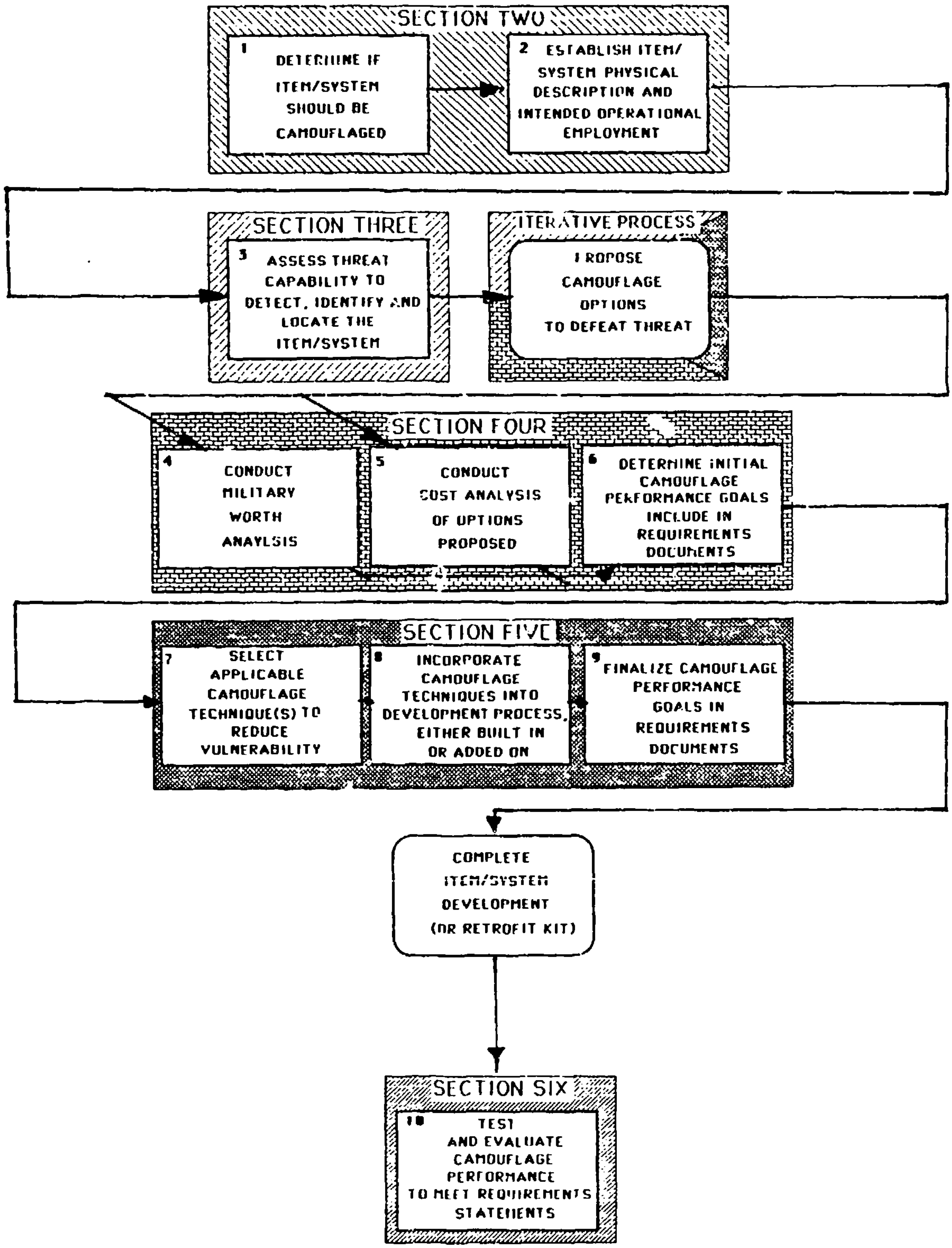
The purpose of this guide is to assist Combat Developers and Materiel Developers, as well as field commanders, to understand the AMC camouflage technology program and options, execute AMC policy in this field, and fulfill the respective responsibilities which AMC/TRADOC Pamphlet 70-2 has assigned to them.

#### 1.2.2 Scope.

This Guide reviews the AMC camouflage program, describes the threat to be countered by the application of camouflage principles and techniques, provides a series of possible camouflage techniques, and describes camouflage testing and evaluation procedures.

Figure 1-1 shows the progression of steps to be taken to achieve successful camouflage of materiel in development. Blocks in the diagram correspond to detailed coverage in sections of this Guide. Within each section, information is presented which illustrates methodologies and rationale in the determination and application of camouflage technology. A more detailed discussion of these steps is presented in Section 1.4.

Figure 1-1. Utility Model for Camouflage Guide.



## 1.3 CHARACTERISTICS OF CAMOUFLAGE

### 1.3.1 Definition.

Camouflage is the use of concealment to minimize the probability of detection and identification of troops, materiel, equipment and installations. Camouflage directly relates to increased survivability, mission accomplishment, and net tactical advantage by reducing the probability of detection, identification and location by hostile surveillance and target acquisition methods. Even in cases where Army units are detected or located, camouflage often results in increased probability of survival. A net tactical advantage is gained by reducing the time or resources available to hostile forces for tracking, aiming and firing at friendly forces. The effectiveness of delivered firepower is reduced by the added uncertainties which camouflage causes to enemy troops in their tasks of finding and firing upon critical targets.

### 1.3.2 Use of Probabilities.

The foregoing discussion can be reduced to a survivability concept commonly used in weapons development. The concept shows the advantages of considering camouflage in development of a new hardware item. The concept takes into account enemy activity, system susceptibility to being found and fired upon, and system vulnerability once hit by enemy fire. The formula provides a very useful tool for examining the needs and solutions for the camouflage of Army systems.

The basic formula states simply that the sum of the probability of survival and the probability of suffering a kill is one. It is usually stated as:

$$P_s = 1 - P_k$$

The probability of suffering a kill consists of a series of probabilities. The first is the probability of enemy activity, a factor necessary to show there must be enemy activity to cause battlefield vulnerability. This is expressed as:

$P_t$ = Probability of Threat Activity

The second set of probabilities is composed of a system's perceptibility to acquisition by enemy forces. This is comprised of three factors; detection, identification, and location. (Location includes those activities that take place to "lock or position" the hostile weapons sensors or ordnance on the targeted system.) These probabilities are stated as:

$P_d$ = Probability of Detection

$P_i$ = Probability of Identification

$P_l$ = Probability of Location

Another set of probabilities is used to take into account the problems of launching, guiding, and detonating the projectile at the targeted system. These probabilities are stated as:

$P_{la}$ = Probability of Launch

$P_g$ = Probability of Guidance

$P_{det}$ = Probability of Detonation

Together the combination of these two probabilities provide an indication of the susceptibility of a system:

$$P_{d\,i\,t} * P_{la\,g\,det}$$

The probability of being hit then becomes:

$$P_h = (P_l) * (P_{d\,i\,t}) * (P_{la\,g\,det})$$

A system which is hit is not necessarily killed. The vulnerability of a system to being killed is a product of the probability of being hit and the probability of a kill, given a hit ($P_{k/h}$). This is stated as:

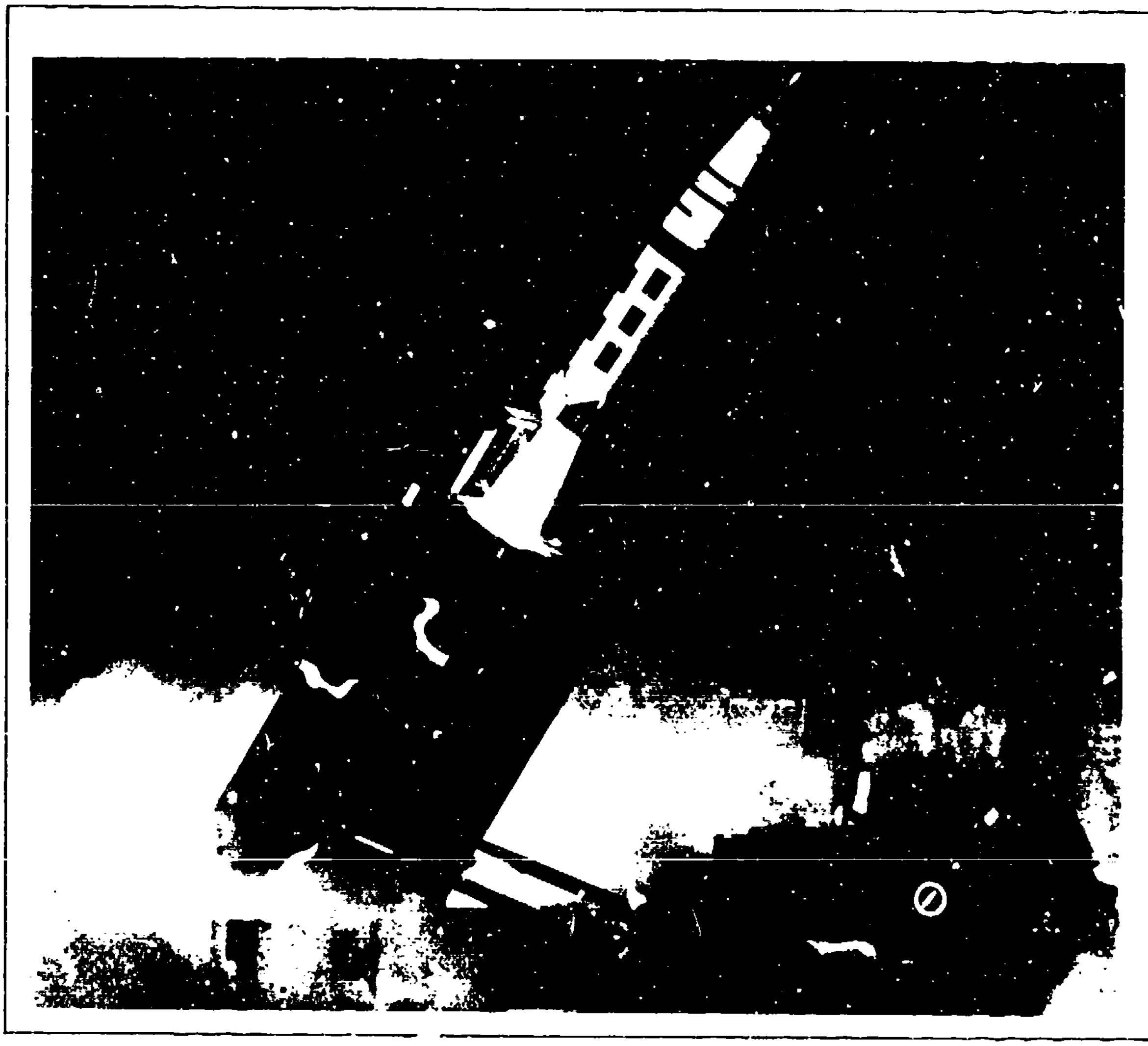
$$P_k = (P_h) * (P_{k/h})$$

The formula for survivability, in an extended form, then becomes:

$$P_s = 1 - (P_l) * (P_{d\,i\,t}) * (P_{la\,g\,det}) * (P_{k/h})$$

The focus of camouflage is on reducing the probabilities of detection, identification, and tracking. Similarly, the related field of deception can reduce the probability of enemy activity in the area occupied by the friendly systems. Other countermeasures can degrade the probability of successful launch, guidance and detonation. Well conceived equipment designs can reduce the probability of a hit causing vital damage to a system. Taken together, then, these factors form a basis which a system developer can use to create a hardware item with significantly improved battlefield survivability.

# IT TAKES MORE THAN WOODLAND CAMOUFLAGE PAINT!



NOTE DESERT TERRAIN, DUST (VISUAL), AND EXHAUST (THERMAL) SIGNATURES.

1.3.3 Types of Camouflage.

Camouflage can be separated into three types which are designated "built-in", "operational", and "field-applied". They are important relative to an item/system's life cycle status, the degree of freedom available in countermeasure selections, and the amount of effort involved in utilization.

Built-in Camouflage. A design feature which is always part of the item/system and requires no thought or application by the field troops constitutes built-in camouflage. Add-on Camouflage is an aspect of built-in camouflage which applies to retro-fit situations, i.e., the camouflage would be built-in if the item/system were new, but would be add-on if the item/system were already fielded. Examples of built-in camouflage include exhaust cooling, shielding, dissipation, structural arrangements to reduce highly reflective geometries, and flash suppressors. Many built-in features can only be used successfully when an item/system is in its concept formulation, engineering development, or early prototype stages.

Operational Camouflage. Troops in field situations practice operational camouflage. It is in response to the local tactical situation and the degree of camouflage applied by the field commander. Included are such matters as sound and light discipline, and the proper use of terrain and shadow in position and movement. Troop training and discipline affect the success of operational camouflage.

Field Applied Camouflage. Troops in the field apply camouflage to themselves or to their equipment by using either locally available materials such as mud, brush, or grass, or materials issued from inventory, such as camouflage screens. More information on camouflage screens and paint can be found in Chapter 5 and Appendix B.

1.3.4 Camouflage Methods.

The methods which are used to camouflage an item's characteristics are not restricted to any given range or form of detection, but will vary depending upon the item/system and the expected sensor threats. This often leads to more specific terminology such as radar camouflage, infrared camouflage and visual camouflage.

## 1.4 HOW TO USE THIS GUIDE.

This Guide contains camouflage development information and procedures which lead to answers to the following key questions:

- What items of Army equipment need camouflage?

- What types of sensor threats must the item/system be camouflaged against?

- How much and what types of camouflage is required?

- What technology is available to meet this requirement?

- How should camouflage techniques and applications be tested and evaluated?

Armed with answers to these questions, the developer may then pursue the acquisition of camouflage in a manner similar to that for all other features required in his item/system development.

Figure 1-1 illustrates both the procedure for acquiring camouflage. Further discussion of those procedures are presented in the other sections of this Guide.

Step 1 in the procedure, as indicated in Figure 1-1 and discussed in Section 2, involves the determination of whether or not an item/system should be camouflaged. Some systems are identified on the Camouflage Critical or Camouflage Sensitive lists. Items on these lists need the tactical benefits of camouflage to increase survivability on the battlefield.

Step 2 in this procedure is to assure that an adequate description is available of the item/system and a description of its intended operational employment. In the event that the item/system is still in the concept stage and not reduced to a military hardware configuration, several descriptions may be necessary to reflect the possible variations in the item/system characteristics. Care should be taken to assure that these descriptions contain data on all aspects affecting detectibility and identifiability.

Step 3 deals with an assessment of the threat and may require the assistance of the Foreign Intelligence Office. This step is described in detail in Section 3 of this Guide. This threat assessment should identify and characterize the enemy reconnaissance surveillance and target acquisition (RSTA) threats that are of greatest concern to the item/system's survivability. The threat assessment consists of comparing an enemy's sensing capabilities with the item/system's physical and operational characteristics in battlefield scenarios and terrains of interest. This assessment leads to statements of specific detection and recognition capabilities expected to be encountered during the life of the item/system.

The foregoing three steps are best accomplished before Milestone Zero, as shown in Figure 1-2. The next action is the identification of camouflage options which can defeat or reduce the threat capability. This is an iterative process which makes use of information from Sections 3, 4 and 5 as the optimum camouflage choices are developed.

| ACTIVITY | MILESTONES 0 | | I | | II | | III | | IV |
|---|---|---|---|---|---|---|---|---|---|
| PHASE | | Concept Exploration | | Concept Demonstration | | Full-Scale Development | | Production & Deployment | |
| FUNDING | 6.1 & 6.2 | | 6.3 | | | 6.4 | | Production | |
| REQUIREMENTS DOCUMENTS | O&O Plan<br>MNS | | O&O Plan | | ROC | | | | |
| SUPPORTING DOCUMENTS | | | TEMP<br>COEA<br>ILSP | | TEMP<br>COEA<br>ILSP | | TEMP<br>ILSP<br>MER | | |
| TESTING | | TFT<br>OFT | | DT<br>EUT&E | | PPT/PPQT<br>OT&E<br>IOT&E | | PQT<br>FOT&E | |
| CAMOUFLAGE STEPS | 1,2,3 | 4,5,6,7,8 | | | 9 | | 10 | | |

Figure 1-2. Camouflage Development Steps in the Materiel Acquisition Process.

The next three steps are explained in Section 4 of this Guide. Two of the steps are conducted concurrently. In Step 4, based upon current threats and descriptions, a military worth analysis is conducted where several levels of camouflage performance capabilities are assumed. At the same time in Step 5 the initial cost of the options are determined. In Step 6 initial camouflage performance goals are developed for inclusion in the draft requirement documents.

The next three steps are covered by Section 5. Step 7 reviews a number of the available techniques and means to achieve the level of camouflage performance capabilities indicated as necessary in Step 6. Step 8 is the activity necessary to incorporate camouflage actions in the development process including supporting documents, funding needs and test schedules.

Step 9 is used to derive final camouflage performance goals. These goals form the basis for a statement of camouflage requirements in the item/system's requirement document. This document is necessary to drive the development and acquisition of camouflage materiel and design for the item/system. Section 5 provides a summary of existing camouflage materiel and contains descriptions of various techniques and methods which impact upon the selection and utilization of camouflage.

Between steps 9 and 10 the equipment item undergoes full scale development and operational testing. The final step, Step 10 is treated in Section 6. Testing is undertaken to determine the item/system's camouflage performance in meeting the requirements goals. This testing leads to acceptance and type classification of the item/system. Section 6 describes test and evaluation methodology and actions necessary and pertinent to determining and evaluating the effectiveness of camouflage.

## 1.5 EXAMPLE PROBLEM

The ten step process set forth above is illustrated in the example problem contained in Appendix E. In the example problem, a hypothetical system is taken through the development process. The intent is to show the importance of considering camouflage as an inherent part of a developing system from the beginning, and as such, how camouflage is considered in each critical developmental stage. By carefully reviewing the example problem the developer can gain insight into these considerations, and can gain a better understanding of the process by which camouflage considerations are treated equally and concurrently with the other critical decisions made by managers in the development process.

## 1.6 USE OF APPENDICES

The main body of this Guide has been kept to a reasonable length by means of placing detailed and descriptive information in several appendices. Appendix A describes the role of camouflage in theoretical and scientific terms. Appendices B and C contain a series of data sheets. Camouflage concepts and systems descriptions are contained in Appendix B while Appendix C sets forth a register of camouflage testing facilities. Appendix D describes the interaction processes between sensors and camouflage systems. The example problem in Appendix E is followed in Appendix F by a discussion of threat reconnaissance, surveillance and target acquisition systems. A developer who, after reading the main body, seeks more detailed information, can begin the search in the appendices. If information beyond that available in the appendices is needed, the staff of the Countersurveillance and Deception Division of the Belvoir Research Development and Engineering Center are available to assist developers by mail or telephone:

Telephone: Commercial (703) 664-6741 or 6771
AUTOVON 354-6741 or 6771

Address: Countersurveillance and Deception Division
Belvoir Research, Development & Engineering Center
ATTN: STRBE
Fort Belvoir, VA 22060-5606

## 1.7 SUBJECTS OUTSIDE THE SCOPE OF THIS GUIDE

Specific camouflage related subjects of interest which are beyond the scope of this Guide are Tactical Cover and Deception, Electronic Warfare, Cryptography, and Aircraft in flight.

Tactical Cover and Deception refers to those integrated measures taken as part of battle plans and may, or may not utilize techniques, materials or equipment that are considered as camouflage. The terms decoy, disguise, and deceive, when used with Tactical Cover and Deception, shield true capabilities and interests while providing evidence of false force capability or intent and is generally performed by combat teams of division size or larger. When applied to Camouflage, the terms decoy, disguise, and deceive are used in a protective sense to cause mis-identification of targets, divide expected attack resources, or serve as a lure to draw enemy fire on a unit. This Guide deals only with decoys and disguises developed for camouflage purposes which are protective in concept. The use of decoys or disguises to achieve tactical deception is not presented.

Electronic Warfare is that segment of military electronics that involves action taken to prevent or reduce an enemy's effective use of radiated electromagnetic energy, and other actions taken to ensure friendly use of radiated electromagnetic energy. EW consists of electronic warfare support measures (listening to and locating enemy radiations), electronic countermeasures (jamming or deception to disrupt the enemy's use of electronics), and electronic counter-countermeasures (protecting friendly communications and non-communications systems). Camouflage and electronic counter-countermeasures share the similar characteristics of being passive, defensive and protective. The use of radar absorbing materials and radar scattering screens could be classified under either discipline. A directive requires consideration of electronic counter-countermeasures throughout the development and production of all equipment and systems dependent upon the electromagnetic spectrum for their operation.

Cryptography and camouflage share a common purpose in denying meaningful and accurate intelligence to an enemy, however their techniques are usually different.

Aircraft in Flight require certain aspects of camouflage outside the scope of this Guide. This Guide only addresses the perceptibility of Army aircraft in a static condition where exposure might provide intelligence concerning military operations or lead to their destruction on the ground.

## 1.8 REFERENCES


1. FM 5-20, Department of the Army Field Manual, Headquarters, Department of the Army, Camouflage, May 1968.

2. United States Army Training and Doctrine Command, TRADOC Pamphlet 70-2, Materiel Acquisition Handbook, March 1987.

3. Department of the Army, Army Regulation 70-1, Systems Acquisition Policy and Procedures, October 1988.

# SELECTION OF ITEMS/SYSTEMS

# FOR CAMOUFLAGE

# SECTION 2

# ITEM/SYSTEM SELECTION

## 2.1 GENERAL

The Materiel Acquisition Handbook jointly published by TRADOC and AMC prescribes a checklist for preparation of the Required Operational Capability (ROC) document. The checklist requires that camouflage be addressed in the ROC for those systems for which camouflage is applicable.

Lists of the applicability of camouflage to a given system have been promulgated by AMC and TRADOC. Selected systems have been designated as either "Camouflage Critical" (CC) or "Camouflage Sensitive" (CS). The lists of materiel falling into the two categories have been published periodically. For example, the list in paragraph 2.8 was reviewed and confirmed by the Combined Arms Center. The listings indicate representative types of items/systems which require camouflage consideration.

The evaluation leading to designation and prioritization of an item/system as camouflage critical or sensitive is established on the basis of a combined estimate of the following factors:

- Value to friendly forces
- Threat posed to the enemy
- Cost to produce/replace
- Priorities of enemy targeting
- Vulnerability to destruction once located
- Effect of loss on other systems
- Life Cycle status of item/system
- Linkage/clues to other high value systems
- Implications of interruption to logistics system

## 2.2 CHARACTERISTICS OF CAMOUFLAGE CRITICAL AND CAMOUFLAGE SENSITIVE

The Camouflage Critical list contains items/systems which are very expensive, have operational capability critical to friendly forces, and/or pose a serious threat to the enemy. Such items/systems as nuclear delivery means and air defense weapons systems are typical of those included on the CC list. CC items/systems tend to be large, relatively few in number, and distinctive in appearance and/or activity.

The Camouflage Sensitive listing contains items/systems which are a combat threat to an enemy and whose operational capability is necessary for friendly force combat operations. Such items/systems are those that equip or support the fighting forces in the field and whose survivability will benefit from reduced perceptibility achieved through camouflage techniques. Trucks are included on the CS list, as well as crew served weapons, repair shops, and other materiel which might reveal the presence or identity of other important items, systems or positions.

Items/systems which are not on the CC or CS lists still may need to be assessed for camouflage needs. Figure 2-1 provides a basis on which to assess an item/system for camouflage consideration.

| FACTOR | CC | CS |
|---|---|---|
| Value to Friendly Forces | critical | necessary |
| Threat posed to Enemy Forces | significant | moderate |
| Cost to produce/replace | high | moderate |
| Enemy Targeting Priorities | high | moderate |
| Vulnerability once located | high | moderate |
| Effect of loss on other systems | significant | moderate |
| Life Cycle status of item/system | new | older |
| Linkage to high value targets | direct | indirect |

Figure 2-1. Assessment Table.

## 2.3 UTILITY OF CC AND CS DESIGNATIONS

Camouflage critical and sensitive designations are used by personnel in HQ AMC to help establish schedule and funding priorities. The placement of items/systems on the camouflage critical list is a method of highlighting their importance to management and command personnel concerned with camouflage. Inclusion on the list also serves to alert developers of their responsibilities to include camouflage aspects in the development process. The development planning of the item/system must emphasize camouflage as one of many requirements. Designations of CC and CS require perceptibility determinations as outlined in this guide. The CC and CS designations relate to the criticality of achieving the camouflage goal and serve as an indication of the resources which should be applied to achieve reductions in perceptibility of the system.

## 2.4 BASIS FOR RANKING ITEMS/SYSTEMS

The CC and CS listings are a compilation of battlefield items/systems that require camouflage. Items/systems appearing on the lists are ranked in order of their priority with respect to the need for camouflage. Items/systems not appearing on the CC and CS lists may deserve to be evaluated for inclusion, or the item/system may be of no concern from a camouflage standpoint to the equipment developer. For example, items such as furniture, hand tools, and engine parts do not appear on the lists and rarely require inherent camouflage.

Within the CC and CS categories are considerations for expenditure of effort to reduce perceptibility of an item/system. The CC priorities are based upon rationale supplied by TRADOC's Combined Arms Center (CAC). The priorities and rationale set forth by CAC are discussed in the following paragraphs:

Nuclear Delivery Systems (1st priority).

*Nuclear Deliver Systems retain their deterrent capability only so long as they cannot be countered. Camouflage contributes to the survivability of the tactical nuclear force (TNF). The survivability of the TNF is a national priority.*

Air Defense Systems (2nd priority).

*Air Defense Systems provide a shield protecting all other elements of the force. Camouflage will enhance the survivability of Air Defense Systems by degrading enemy visual and electronic target acquisitions and targeting systems. Loss of Air Defense will expose the entire force to destruction by enemy air assets.*

Command and Control Nodes (3rd priority).

*Command and control nodes synchronize and direct the actions of all other units and activities. The loss of C&C will severely degrade the effectiveness of the entire force. Camouflage is a major contributor to command post survivability.*

Logistics Units and Installations (4th priority).

*Logistics are the backbone of sustained combat. It is extremely difficult to improve the survivability of these unit by increasing mobility or ... (dispersion since) ... they are inherently soft. Camouflage is an effective means of improving their survivability.*

Combat Maneuver/Aviation Units (5th priority).

*Combat maneuver/aviation units are inherently survivable. They achieve survivability through maneuver, hardening, dispersal, camouflage and the generation of combat power. Camouflage is one of the contributing factors.*

## 2.5 LIST OF CAMOUFLAGE CRITICAL ITEMS/SYSTEMS

The five priorities within the CC category, with appropriate examples, are shown in Figure 2-2.

## 2.6 LIST OF CAMOUFLAGE SENSITIVE ITEMS/SYSTEMS

There are thirteen levels in the CS category as set forth in Figure 2-3.

## 2.7 PHYSICAL DESCRIPTION AND OPERATIONAL EMPLOYMENT

Once the need for camouflage of an item/system under development has been established, the parameters which will determine the type and degree of camouflage must be set forth. This determination often will be accomplished in conjunction with drafting of the Operational and Organizational Plan (O & O Plan) as shown in Figure 1-2.

An item/system with significant bulk, radar reflectivity, and heat emissions will need to have counter-surveillance aspects built into the system as it progresses through development. Similarly, an item/system which operates well forward in the combat zone is more exposed to threat surveillance than an item which operates well to the rear.

| CAMOUFLAGE CRITICAL PRIORITIES | CATEGORY OF MATERIEL | EXAMPLE SYSTEMS |
|---|---|---|
| 1 | Nuclear Delivery Means | Pershing, Lance, 155 mm guns, SASP |
| 2 | Air Defense Systems | Chapparal, Hawk, Nike-Hercules, Redeye, Patriot, Roland, SAM-HIP, Stinger, ATAADS |
| 3 | Command and Control Nodes | Antennas, dishes, Fire Direction Systems, Air Defense Command and Control, Communications Centers, Analysis Centers |
| 4 | Logistics Units | Generator sets, heaters, stoves, ranges, large tents |
| 5 | Combat Maneuver/ Aviation units | Tanks, Armored Fighting Vehicles, AVLBs, SP guns, Attack helicopters, AT missiles, tank recovery vehicles, Forward Area refueling equipment, observation and utility helicopters |

Figure 2-2. Camouflage Critical Items/Systems.

| CAMOUFLAGE SENSITIVE PRIORITIES | CATEGORY OF MATERIEL | EXAMPLE ITEMS/SYSTEMS |
|---|---|---|
| 1 | Field Artillery and CB/CM Radars | 105 mm Howitzers & Guns<br>CB/CM radars |
| 2 | Ground Surveillance Radar | Radar Sets, all types |
| 3 | Brigade/Battalion headquarters | Antennas, stoves, heaters, generators, radio sets, light vehicles, refueling and water vehicles |
| 4 | Anti-Tank Devices | Dragon, TOW, LAW |
| 5 | Individual Soldier Equipment | BDU, Field Jacket, Poncho, boots, body Armor, Load Carrying Equipment, gloves, underwear, hankerchiefs, tents, small arms, mortars |
| 6 | Ammunition | Small arms, mortar, howitzer and gun ammunition, rockets, missiles |
| 7 | Tactical POL | Bulk storage equipment, collapsible tanks, pumps, pipelines, trailer-mounted fuel labs |
| 8 | Support Aircraft | CH 47, CH 54 |
| 9 | Tactical Bridges | Ribbon, MGB |
| 10 | Trucks | Cargo, medium and heavy |
| 11 | Combat Engineer equipment | Dozers, cranes, loaders, graders |
| 12 | Logistics Support equipment | Maintenance shops, MILVAN containers, forklifts |
| 13 | Other high signature items with wide distribution | generators, antennas, heaters, stoves |

Figure 2-3. Camouflage Sensitive Items/Systems.

### 2.7.1 O&O Plan Content.

Several sentences of the O&O Plan are applicable in the camouflage determination process. The threat paragraph should include consideration of surveillance means as well as weaponry. The Operational Plan includes various aspects of how the system will interface with other systems. Exposure to enemy surveillance as it operates in various conditions must be considered. The system constraints sentences may need to describe significant counter-surveillance problems anticipated for the system, if applicable.

### 2.7.2 Consultation.

Assistance in establishing the counter-surveillance aspects of the item/system description and operational employment is available from the Belvoir Research Development and Engineering Center. Extensive experience and data from previous development efforts can be used often for rapid response to combat and materiel developers.

## 2.8 REFERENCES


1. Letter, ATZL-CAC-I, TRADOC-CAC, 30 April 1985, "TRADOC-AMC Camouflage Critical/Sensitive List."

2. Pamphlet, AMC/TRADOC 70-2, 26 March 1987, "Materiel Acquisition Handbook."

# THREAT TO CAMOUFLAGE

RECONNAISSANCE, SURVEILLANCE AND TARGET ACQUISITION

SECTION 3

# THREAT TO CAMOUFLAGE

## 3.1 GENERAL

The purpose of this section is to discuss for the equipment developer a variety of means by which an enemy force can detect, identify and locate friendly items of equipment. The concept set forth in Section 1 stated that the probability of surviving on the battlefield could be expressed as a combination of other probabilities:

$$P_s = 1 - (P_e) * (P_d \; i \; l) * (P_{h \; g \; e}) * (P_{k/h})$$

The focus of the enemy is to increase all of the probabilities on the right side of the equation while the friendly force seeks to keep the probabilities as low as possible.

The portion of the equation most influenced by effective camouflage is the subset dealing with detection, identification, and location. Since the threat forces seek to enhance their ability to accomplish these three functions using the most effective means possible, a knowledge of the activities/advances is necessary. This section describes that threat against which a developer must take offsetting action.

The flow of activities necessary to assess the threat to a developing system is shown in Figure 3-1. The characteristics of the item/system, established previously, are used as a basis for the process. This is supplemented by a discussion of generic detection and identification processes. Once the processes are understood in general, then the specific enemy capabilities to sense the new system are established. At this point it can be determined if the enemy will have sensors capable of detecting the equipment. If so, the next step is to determine whether or not the resolution of that sensing poses a significant detection hazard to the item/system. This determination is followed by an evaluation of the probability of the item/system encountering the threatening sensor. If an encounter between the capable sensor and the item/system is likely, then action needs to be taken to reduce the detectibility/identifiability of the item/system. The contents of this chapter are arranged to support this sequence.

## 3.2 INTELLIGENCE ON THE BATTLEFIELD

### 3.2.1 Background.

Historically, camouflage has contributed to the military commander's success in concealment and deception. Hence, there is long-standing desire to determine the THREAT that may detect, identify, locate friendly forces and endanger their survivability

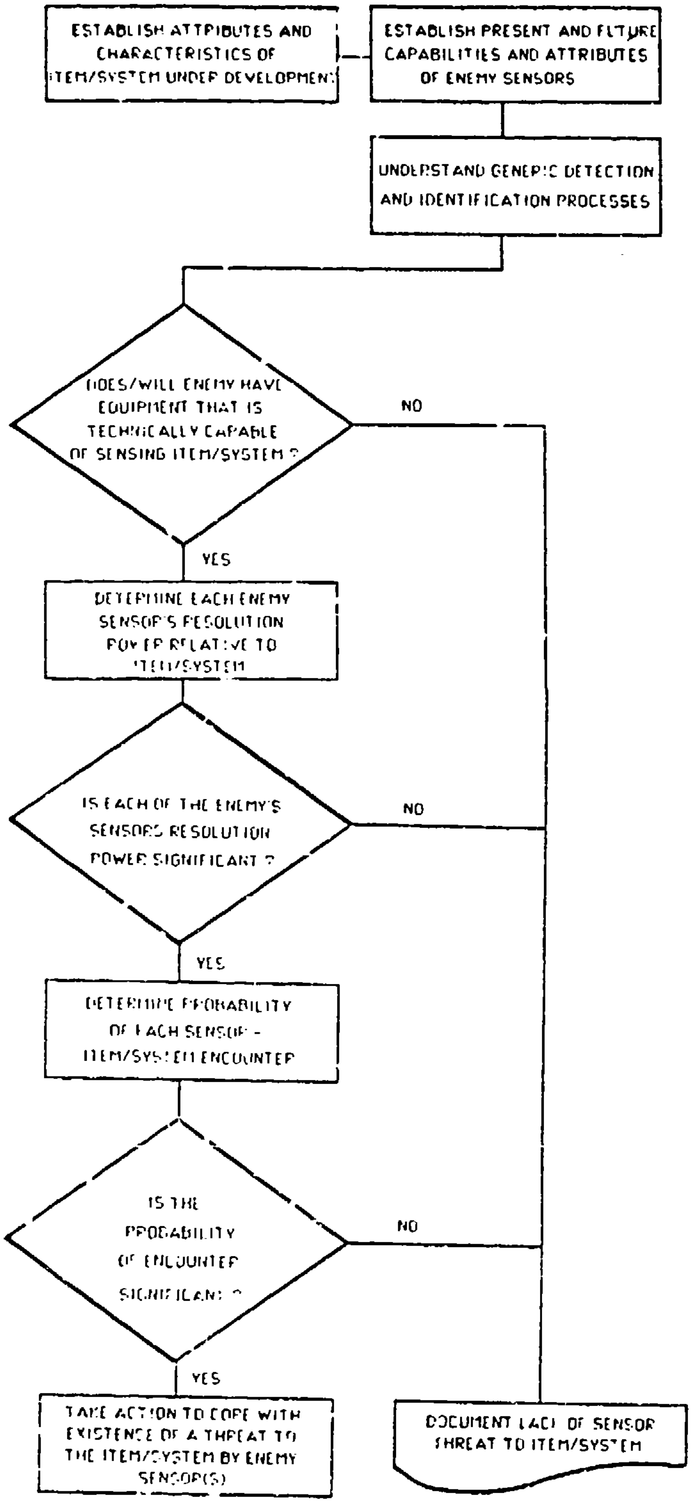



Figure 3-1. Threat Assessment Process.

or effectiveness. The threat to camouflage, concealment and deception (CCD) consists of reconnaissance, surveillance, and target acquisition (RSTA) assets that make up the integrated systems through which opposing ground and air forces may acquire, analyze, and disseminate tactical and operational intelligence data on friendly forces.

Military commanders recognize that the enemy seeks timely intelligence to assure acquisition of tactical and operational data on which to base operational decisions. Camouflage assists in defeating this effort by concealing truth on the battlefield. Camouflage impact on the intelligence product resulting from enemy collection efforts by distorting the evaluation, analysis, and interpretation of the information collected.

Threats considered in the development of CCD materiel are those used in the development of the Army 21 and AirLand Battle 2000 concepts. The U.S. Army can expect to be required to conduct combat operations in many different parts of the world, against enemy forces of varying degrees of sophistication, and at different levels of intensity. Future battlefields are expected to be populated with advanced weapons systems with greater reach and increased lethality, combat vehicles with greater speed and mobility, improved RSTA sensors and data processing systems incorporating high technology computers and telecommunications.

The threat forces can be expected to present a broad range of sophistication in RSTA equipment and techniques, both air and ground to support combat operations. The threat will have the capability to collect data throughout the target signature spectrum including visual, electro-optical, sound and flash ranging, radio-intercept/RF (SIGINT), IEW/infrared, thermal detection, broad spectrum photographic imagery, and other electronic systems to augment human resources (HUMINT) in gathering intelligence data and acquiring targets (Reference 2, p. 3-16). The specific role of camouflage against these threats is highly scenario dependent.

The threat sensors/systems must be understood so that any deception "story" can be fed to the enemy commander through them while at the same time preventing the discovery of friendly camouflage. Enemy target acquisition and intelligence gathering systems will challenge the camouflage systems to stand up under close scrutiny.

Quantities of various types of sensor systems employed by threat forces will differ significantly from one situation/scenario to another. The numbers of each type of sensor system encountered will depend on who the enemy is, the size of the force, its deployment, its mission/maneuver at the time of encounter, and the priorities assigned in allocating RSTA resources and support. For example, during the tactical march, it is usual that only a portion of threat RSTA would be deployed as a general rule. After initial contact with opposing forces, the full range of intelligence and target acquisition systems (e.g. aerial observation, counter-battery radar, sound ranging, radio/radar intercept) from regiment/division reconnaissance units would become operational. Camouflage systems must be aware of the potential cues provided by these systems. In a deliberate attack situation/scenario, RSTA elements would be fully engaged in gathering information on friendly forces, acquiring targets and engaging in radio-electronic combat at all echelons of the attacking force.

Hence, the military commanders regard CCD as promising contributors to successful maneuver and a force multiplier. Increasing survivability extends the forces' capabilities and contributes to achieving an edge in battle. The epitome of successful camouflage lies in hiding the true situation while deception suggests a false one that misleads the enemy and induces him to act counter to his own best interests.

3.2.2 Threat Assumptions.

The threat to camouflage arises from several sources, some of which are unpredictable. The natural threat, in terms of weather, terrain, sun/sky illumination and natural backgrounds can be defined and largely anticipated. Hence, there are camouflage screens and other techniques for wooded, desert or arctic backgrounds. However, the enemy threat consists of technical capabilities, doctrine, RSTA deployment and the likelihood that the camouflage will encounter varying RSTA sensors on the battlefield over time.

The threat doctrine generally can be determined and the types of sensors, surveillance systems used and procedures for target acquisition and fire direction can be postulated. Whether or not specific RSTA equipment will be deployed is less certain and the likelihood that a given system will encounter a specific RSTA threat is scenario dependent.

The greatest uncertainty for the camouflage user is the characteristics and performance of enemy RSTA items/systems and the degree of efficiency the enemy can achieve in utilizing the intelligence information acquired by his sensors (Reference 3, p. 3-17). Technological uncertainties about the enemy threat will require assumptions in one or more of the following areas:

- The level (low-, mid- or high-level) of the RSTA threat.
- The degree to which the RSTA sensors are capable of utilizing all of the electromagnetic (EM) spectrum in their surveillance or other coverage.
- The speed of intelligence communication and information fusion.
- The number of levels of computer/data processing/C3I decision making are present.

- The possibility of more sophisticated than expected enemy RSTA capabilities.

These and other assumptions about the threat to camouflage may reduce the distinctions between different threat levels by anticipating RSTA upgrades and the availability of advanced weapons technologies among an the threat population. Clearly, there are significant probabilities of encountering higher RSTA capabilities.

## 3.3 CAMOUFLAGE SYSTEMS THREAT

### 3.2.1 Operational Concepts.

It is useful to consider surveillance and target acquisition threats separately because they have significant differences. Surveillance consists of observing an opposing force for the purpose of obtaining information about force disposition, composition, readiness state, lines of supply, etc. Target acquisition detects, recognizes, identifies, and locates specific item/systems which become targets. Target acquisition denotes imminent peril for the item/system which has been acquired and, therefore, deserves high, short-term priority countermeasure effort. Surveillance threats represent a serious over-all problem, but there usually exists a time lag of at least several minutes to hours between detection and response based on the intelligence derived from this detection.

The camouflage task to defeat surveillance is in some ways more difficult than defeating target acquisition. The surveillance function typically will have greater resources such as a greater variety of more sophisticated sensors and processes, better facilities, more time, greater foreknowledge, rested and more specifically trained personnel, etc. It is also noted that target acquisition may or may not have a human in its data processing loop, whereas the surveillance system invariably will contain a human interpreter, analyzer, etc. This affects the flexibility which is available in the countermeasure response.

Camouflage is concerned with defeating target acquisition as a fundamental point of survival. Camouflage can be more effective in this role than in combatting surveillance because the impact of time delays imposed on aiming, firing and guiding sequences can be decisive in defeating the attacking weapon system.

### 3.3.2 Transmission Means.

Surveillance prevents tactical surprise by detecting, identifying and interpreting attack indicators. Target acquisition detects, identifies, and locates a target in a combat environment so that a weapon can be accurately delivered.

In recent years, airborne attack sensor-weapon systems have found widespread use (e.g., forward-looking infrared (FLIR), low-light-level television (LLLTV) systems, and synthetic-aperture radar (SAR)). Air-deliverable weapon systems, having sophisticated terminal guidance sensors, have also been developed. These include laser-guided bombs, electro-optically guided munitions, and imaging infrared guided weapons (Reference 4, p. 3-17).

Remote sensing systems for RSTA tend to be complex systems that require detailed knowledge about their design and operation to know how to defeat them. The physical means by which information about a target object is conveyed to the remote sensor is critical. The most important means are electromagnetic and mechanical which are discussed in following paragraphs.

Electromagnetic radiation is the most widely used energy for sensor input. This encompasses energy ranging from gamma rays on the high end of the frequency range (Figure 3-2) to radio and inductive waves on the low frequency end and includes visible light, ultraviolet, infrared and microwave spectral regions. EM radiation interacts with matter in ways described as reflection, transmission, refraction, absorption, and scattering. Within the limits of interest to tactical camouflage, EM radiation follows line-of-sight and obeys the inverse square law. Human sight is sensitive to only a very small window (0.38 to 0.78 micrometer wavelengths) in the EM spectrum. Other sensors respond to radiation outside the visual range, some being sensitive to a single frequency and others being sensitive to both narrow and broad bandwidths. Descriptions of these radiation bands usually include frequency, intensity, and a title such as visual, infrared, etc. EM remote sensing means are a major concern for camouflage.

Mechanical wave propagation is divided into two subdivisions, sonic and seismic. Mechanically induced waves originate by a physical vibration which imparts energy to the transfer medium, usually air for sonic and earth for seismic waves. These waves travel through the medium, being modified by the variations within the medium, such as density, temperature, etc. Description of these energies usually include their frequency or wavelength, amplitude and phase. Sensors that rely on mechanical energy transmissions for input are classed as moderate threats, except for artillery spotting (Reference 1, p. 3-16).

### 3.3.3 Target Signatures.

Ground target signatures are descriptive sets of data acquired by remote sensor observations and measurements. Data in the visible, infrared and microwave regions of the EM spectrum can be used to characterize both natural and man-made objects and natural backgrounds. Target signatures can uniquely distinguish targets from backgrounds and one target from another (Reference 5, p. 3-17).

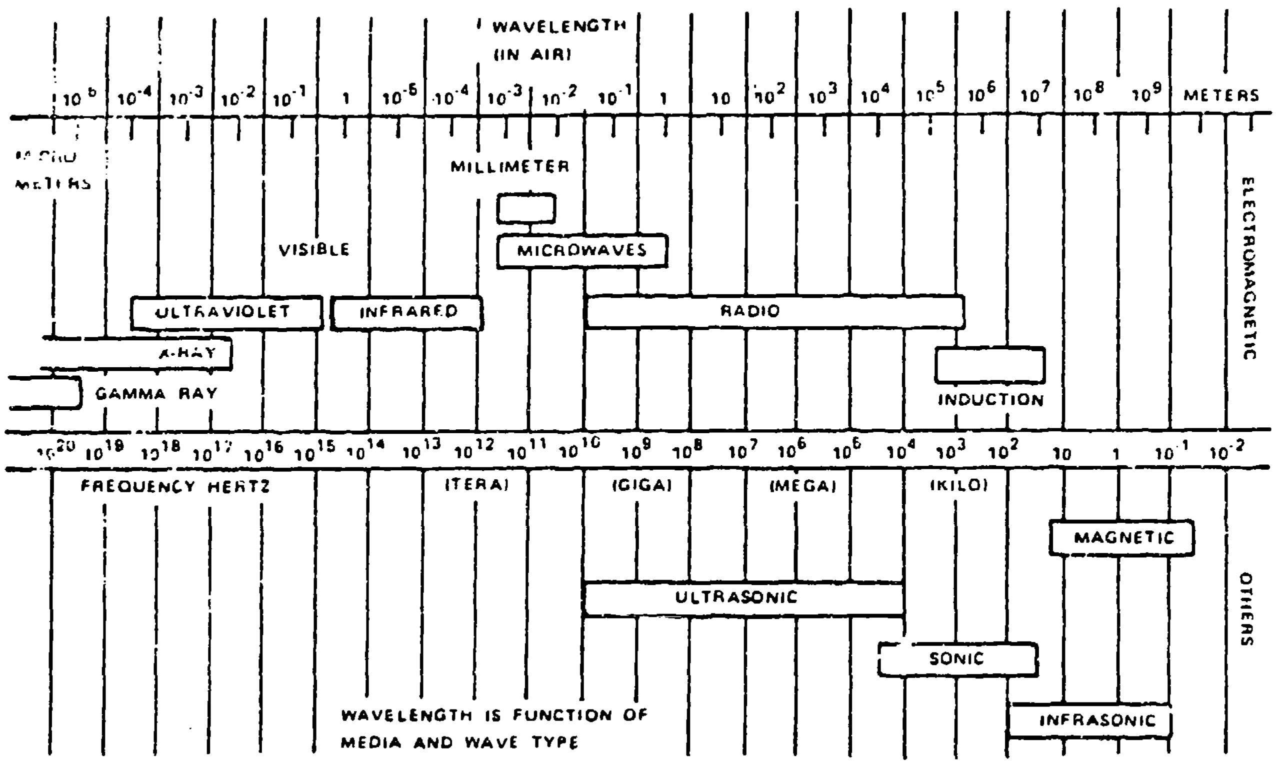



Figure 3-2. The STANO Energy Spectrum.

Typical target signature cues relevant to characterizing tactical items/systems include the following:

- Size
- Shape (profile, shadow casting, straight lines, etc.)
- Spectral reflectance
- Luminance contrast
- Motion
- Emissivity

- Surface temperature
- Radar cross section (flat, metallic surfaces)
- Acoustic intensity and frequency (characteristic pattern)
- Electromagnetic pulse intensity and frequency

3.3.4 <u>Collection Means</u>.

Sensors which serve to detect the information conveyed electromagnetically or mechanically can be grouped into six generic categories (Reference 1, p. 3-16):

- Human Eye
  - Unassisted
  - Assisted
    - Binoculars, Periscopes
    - Night Vision Devices
    - Low Light Level Television

- Photographic
  - Ultraviolet
  - Black and White
  - Infrared
  - Camouflage Detection
  - Color

- Infrared
  - Line Scanners
  - Forward Looking IR (FLIR)

- Laser
  - Target Designators
  - Rangefinders
  - Scanners

- Microwave Radar
  - Side Looking Airborne Radar (SLAR)
  - Synthetic Aperture Radar (SAR)
  - Battlefield Surveillance Radar
  - Moving Target Indicator (MTI)

- Indirect-Fire Locating Systems
  - Sound
  - Flash
  - Electromagnetic Pulse (EMP)

3.3.5 Sensor Characteristics.

The prime operational characteristics of battlefield remote sensing systems are effective range, resolution, spectral region of operation, and sensitivity.

3.3.5.1 Effective Range. Effective range for a given sensor depend upon target-to-background contrast, the signal strength involved, and the transmission losses. An effective range specification is an indication of a safe stand-off distance in an encounter between a sensor and a target beyond which the sensor most likely will not detect the target. This range, in combination with the range of the sensor platform, indicates those areas of the battlefield where detection by the sensor is possible. Hence, most short range sensing systems are encountered on the battlefield while airborne or satellite-borne sensors may be encountered worldwide. Camouflage can be instrumental in decreasing the effective range of remote sensors (Reference 6, p. 3-17).

3.3.5.2 Resolution. Resolution is a measure of the degree of detail of some phenomena or scene that a sensor system can indicate or display. Increased resolution capability of a sensor system gives the interpreter more information to consider and hence, requires an increase in camouflage sophistication to deny identity cues.

The resolution of an imaging type sensor with a raster scan or television type display is a function of the scan line spacing. A typical relationship between recognition probability or identification probability and the number of scan lines across images of military vehicles is shown in Figures 3-3 and 3-4 (Reference 1, p. 3-16).

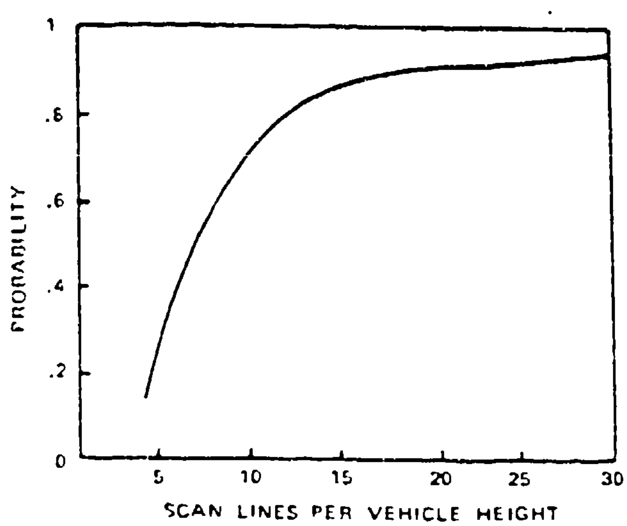



Figure 3-3. Probability of Identification Versus Lines per Vehicle Height.

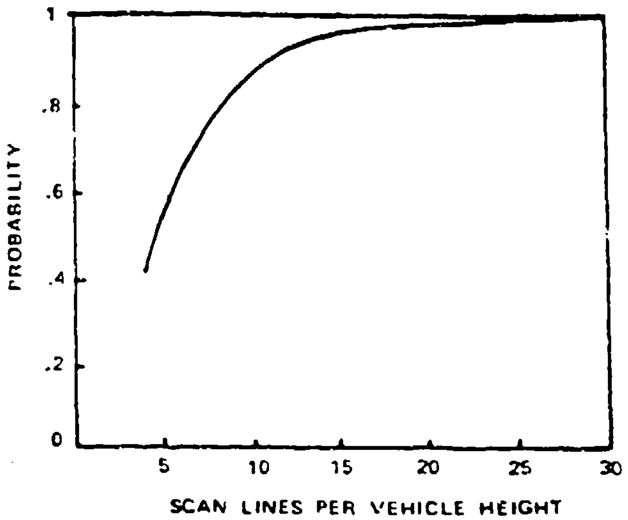



Figure 3-4. Probability of Recognition Versus Lines per Vehicle Height.

Statements about the sensitivity of a sensor system indicate the minimum target-to-background contrast that can be detected. These are usually statements of noticeable differences in apparent temperature, radar cross section, color, shape, speed, depth, distance, etc. The significance of the target/background relationship is evident in the definitions of certain parameters that are critical to some target acquisition processes (Reference 5, p. 3-17):

$$\text{Contrast} = \frac{(\text{target brightness}) - (\text{background brightness})}{(\text{background brightness}}$$

$$\text{Inherent contrast} = \frac{\dfrac{(\text{target radiant intensity})}{(\text{projected target area})_{avg}} - \dfrac{(\text{background radiant intensity})}{(\text{projected background area})_{avg}}}{\dfrac{(\text{background radiant intensity})}{(\text{projected background area})_{avg}}}$$

$$\text{Modulation contrast} = \frac{(\text{target radiance}) - (\text{background radiance})}{(\text{target radiance}) + (\text{background radiance})}$$

Threshold or
limiting resolution = the highest spatial frequency in a pattern (e.g., sine wave, bar, etc.) which can just barely be detected as the pattern's signal-to-noise ratio is varied.

When the targets and their backgrounds are paired with various tactical sensors, assessment of contributing elements of the target signatures requires quantitative measurement of:

(1) Target/background characteristics and attributes,
(2) The environments affecting propagation and transmittance of the inherent target/background characteristics,
(3) The modulation imposed by the sensor/processor/display in viewing the target scene, and
(4) The perception of that target scene or sensor image by the human observer.

The many and varied tactical backgrounds against which targets must be discriminated include natural soils, vegetation, and horizon sky, the meteorological/seasonal variants of these and man-made backgrounds such as concrete, asphalt, wood, paint, fabric, and metal surfaces. The extreme variabilities of the possible tactical backgrounds and their characteristics (e.g., reflectance, emittance, illuminance, color, texture, and especially clutter) present major problems in the determination of RSTA sensor responses in terms of probabilities of detection, recognition and identification (Reference 7, p. 3-17).

3.3.5.3 Spectral Region. Remote sensing systems generally operate in relatively narrow bands of the EM spectrum. Knowledge of these bands aids the camoufleur since the target needs to match the characteristics of the background in only that band to defeat the sensing system. For example, camouflage detection film is used for wavelengths in the 0.6 to 0.9 micron band so that camouflage to defeat this film need match the background only in this band. In particular, military coatings need to match the reflectance of chlorophyll in the 0.6 to 0.9 micron band; the difference in reflectance between the coating and chlorophyll is of no interest outside this band. However, broad band or multi-band sensors are beginning to appear in the battlefield RSTA mix (Reference 2, p. 3-16).

3.3.5.4 Sensitivity. Some missile seekers are sensitive to a narrow band of near infrared radiation and are attracted to reflected sunlight. The camouflage to defeat these seekers is a coating with low reflectance in this band. The visual color of this coating is of no consequence to the seekers since the seekers cannot "see" in the visual band (Reference 8, p. 3-17).

The general procedure for determining the camouflage treatment of an item/system against a sensing system is to separately investigate the item/system and the background with instruments sensitive to wavelengths in the bands of interest. Differences should be minimized by the camouflage treatment.

3.3.6 Environment.

The battlefield environment limits technical performance as well as operational uses of RSTA sensor systems. These considerations must be factored into the estimates of the threat posed by enemy RSTA.

The atmosphere is not uniformly transparent to all wavelengths of EM radiation; the spectrum has "window" areas (Figure 3-5) of relatively high transmittance in which remote sensors operate best. These are the regions of the spectrum in which usable fractions of the energy from the target can be most easily collected by the sensor. These natural windows constrain the choice of possible wavelengths of operation for some threat sensor systems (Reference 1, p. 3-16).

Terrain features are an obvious environmental consideration for line-of-sight sensors, although certain radars have the ability to "see" through foliage.

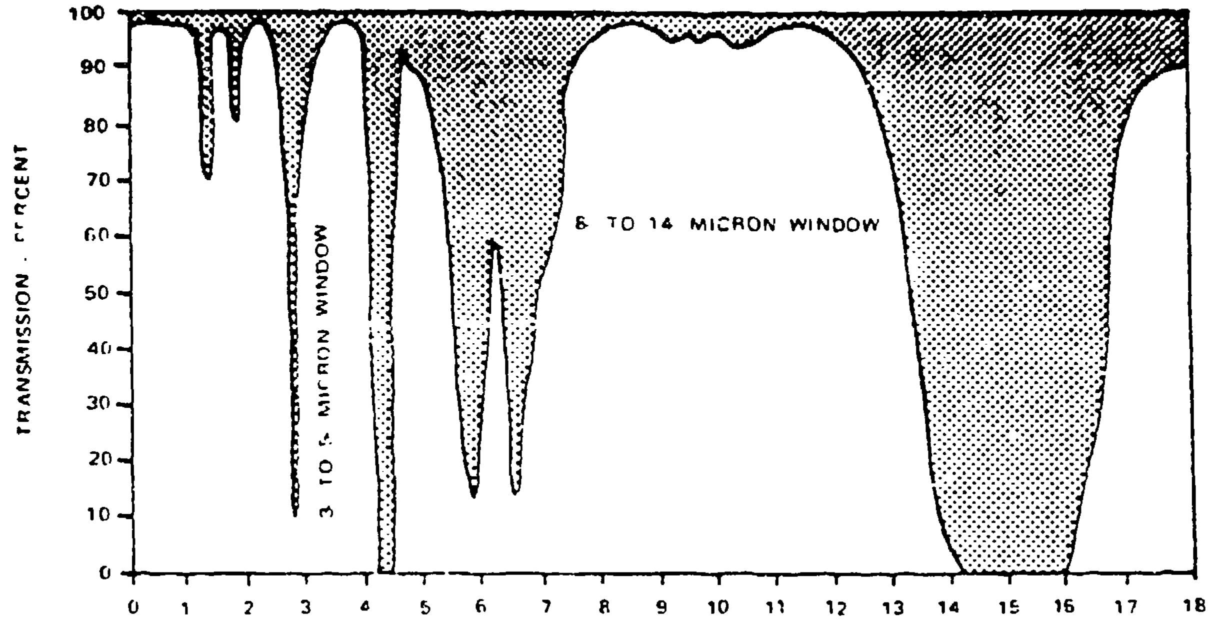
Clutter caused by complexity of the background has the greatest effect on the performance of the sensor and the sensor operator. Detection of a single target against a uniform background that strongly contrasts with the target is a best-case situation which is not typical of the battlefield environment. Ground based radar detection of an aerial target is an example of such a situation. The ability of the sensor operator to distinguish between the target and the background degrades as the complexity (clutter) of the background increases. The visual complexity of open woodland is a familiar example.

Sensor systems are also sensitive to seasonal changes in the background. UV photographic systems which exploit differences in reflection between white objects and snow are ineffective when the background changes from winter snow to summer foliage. Photographic camouflage detection systems, which exploit differences in reflection between green coatings and chlorophyll, are less effective in the absence of foliage. Sun angle (or presence) will affect visibility range and shadow casting. Moonlight is a factor in night vision.

## 3.4 THREAT ASSESSMENT

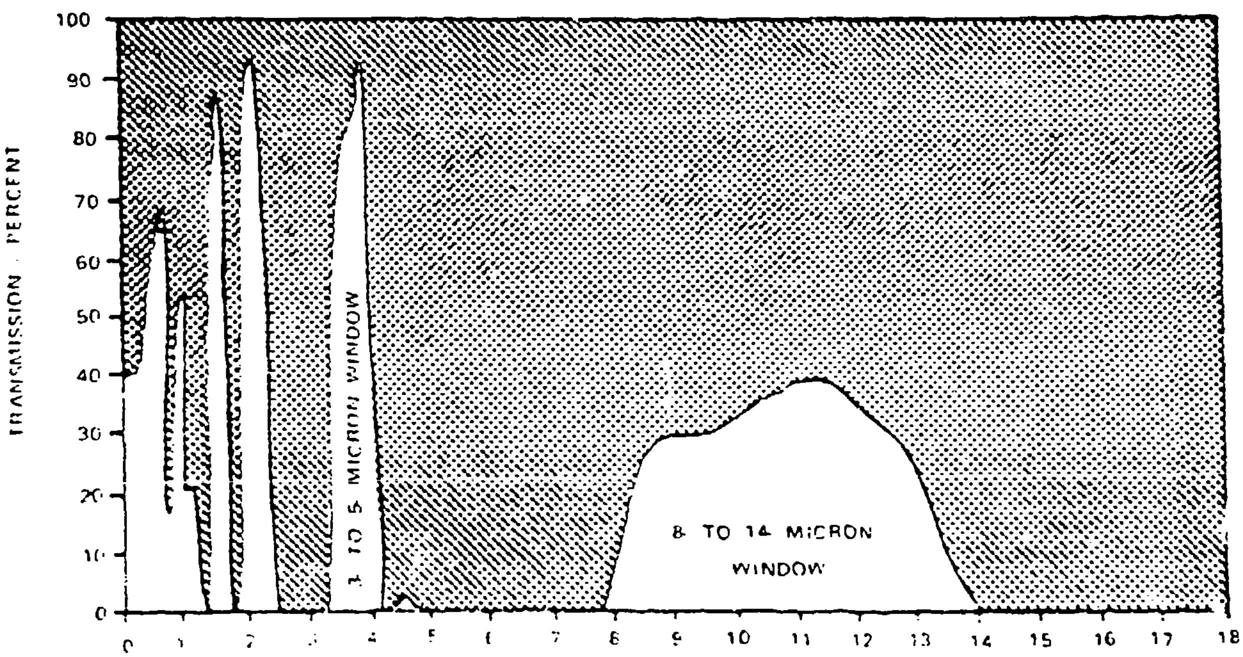
Threat assessments of potential opponent capabilities and the postulated intentions of projected hostile forces compare the qualities and attributes of these forces with friendly forces' doctrine, missions, capabilities and attributes. Information obtained from the designated Foreign Intelligence Offices (FIO) in the form of processed intelligence, capability estimates, mirror image analysis, and other source materials contributes to the materiel developer's, combat developer's, and field commander's determination of what types of camouflage may be required for their items/systems/operations (Reference 2, p. 3-16).

BRDEC offers substantive capability to assist the users of this Guide to Camouflage with the threat assessment. A primary mission of BRDEC is to support equipment developers in meeting their overall responsibilities for implementation of camouflage. Such assistance can be provided at any negotiated level of effort ranging from minor consultations to complete systems-specific threat assessment as well as specific component/subsystem threats.




WAVELENGTH - MICRONS

LOW HUMIDITY




WAVELENGTH - MICRONS

HIGH HUMIDITY

Figure 3-5. Atmospheric Infrared Transmittance at Sea Level.

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3.4.1 Trends.

The enemy threat to be considered in the development, as noted previously, is basically that postulated for the Army 21 and AirLand Battle 2000 concepts. These doctrinal positions provide direct statements of user needs as well as implied requirements that, when coupled with evolving current doctrine and technology applications, help to define essential characteristics of camouflage materiel requirements.

The Army can expect to be required to conduct combat operations in many different parts of the world against enemy forces of widely varying degrees of sophistication and at different levels of intensity. The capabilities of threat RSTA to provide information to the opponent on friendly forces and targets will vary over a considerable capability range (Reference 3, p. 3-17). At the lower end of the capability scale, the opportunities for CCD are those directed against the human eye, both aided and unaided, as represented in ground patrols, ground observers and air observers. These system specific target attributes include relevant characteristics of the targets such as size, shape, texture, color, reflectance, luminance and the background and environment conditions that influence the processes of target detection, recognition and identification. At this level, the human ear, augmented by sound ranging systems and radio direction finding (DF) systems, can provide useful cues to supplement and direct the human eye in finding and observing targets.

At higher levels of threat sophistication, the target acquisition and intelligence gathering systems will include photographic reconnaissance sensors, radar systems and infrared systems, each of which utilize different portions of the EM spectrum in supporting RSTA operations and may employ either ground or air platforms.

At the high end of the threat spectrum, threat forces are expected to possess highly sophisticated target acquisition and intelligence gathering systems, especially in Central Europe. Threat forces would be expected to use a broad range of RSTA equipment and techniques, both air and ground, to support their combat operations. The high level threat includes visual, electro-optical, radar, infrared, photographic, ELINT/COMINT systems, radio intercept/DF as well as space-based elements of all types to gather intelligence information and target data and to communicate/distribute that information/data on a near-real-time basis. In addition, the future battlefield is expected to be populated with advanced weapons systems with sophisticated sensors and weapons of longer range and increased lethality. Improved combat mobility and speed -- hence increased likelihood of target encounters -- will be accompanied by upgraded target acquisition, intelligence gathering and data processing systems exploiting the rapid advances in computer/software technology. These high technology systems -- employed singly and in combination -- will challenge the camouflage systems to stand up under intense, agile, multi-sensor scrutiny (Reference 2, p. 3-16).

A more detailed discussion of trends can be found in Appendix F.

3.4.2 Sources of Intelligence.

Primary sources of information on potential or existing enemy RSTA threats are the FIO at each major subordinate command, laboratory or center (Reference 2, p. 3-16). Materiel and combat developers can obtain from these sources a validated threat for their particular item/system. The FIO comprises the principal point of contact between developers and the intelligence community (see AR 381-11 and DA Pamphlet 381-14).

Estimation of enemy capabilities at any given time is never perfect. In fact, the confidence factor associated with some intelligence data may be quite low or certain information may be lacking completely. At times, the mirror image approach is useful in the absence of reliable information. Mirror imaging assumes the enemy has achieved capabilities comparable to those of the U.S. Of course, this approach ignores the possible reality of technological surprise when enemy capabilities are, in fact, more advanced than those of the U.S. It may also do the opposite and choose selected U.S. advantages in certain specific areas. In addition, mirror imaging assumes that enemy development goals parallel those of the U.S. whereas it is possible that the enemy may achieve some equivalent effectiveness in combat by following a low-technology, high-redundancy approach when the U.S. has followed a high-technology, low-redundancy path. Nevertheless, mirror imaging can be used to avoid important gaps in threat assessment as the need arises.

## 3.5 LIKELIHOOD OF ENCOUNTER WITH RSTA SYSTEMS

To detect the presence of a friendly target, a RSTA system must be present and operating. For given scenarios, the probability of encounters between targets and sensing systems is dependent upon the availability, reliability and density of sensor coverage on the battlefield. Some areas of the battlefield may be subjected to 24 hour surveillance; other areas may have only occasional coverage. The mission, tactical maneuver, and expected number of targets on the battlefield and their usage doctrine effects encounter probability (Reference 3, p. 3-17).

RSTA sensor system availability depends on some combination of natural events, design features, and employment doctrine. For example, normal aerial photography is limited to periods of low cloud cover, good visibility, and daylight. The daylight restriction can be removed by a willingness to use artificial battlefield illumination sources. Some IR systems perform equally well in the day or night, but still are restricted by adverse weather conditions. Some radars come close to being true all-weather day-and-night remote sensing systems. The mission time of some sensor systems and satellites may be limited by power supply.

The density of coverage depends on the number of RSTA systems available for use and the employment doctrine for these systems. Human eyes are still the primary threat because of the sheer number available. At the other extreme, some sensor systems are so costly that the few available are restricted in their employment to search only for targets of extremely high value.

The Developer must assess the enemy inventory and doctrine surrounding each threat sensor which may be employed against his system. An evaluation can then be made of the likelihood of each threat sensor being present in a tactical setting, and the relative worth that the sensor system operator would place on the developers equipment. The results of this evaluation forms the basis for establishing the likelihood of encounter with a threat RSTA system.

## 3.6 SUMMARY OF THREAT TO ITEM/SYSTEM

Up to this point the developer has come to appreciate the sensor situation impacting on his emerging system. A record has been made of those assessment which disclosed that only a minimal threat is posed to the emerging item/system by enemy sensors. On the other hand, a record has been established for those assessments which showed that there is a perceptibility of the system to existing or emerging threat sensors. This is necessary in preparation for an assessment of the value of the unaltered system compared to the value of the system after measures are taken to reduce its perceptibility to threat systems. This activity will be described in subsequent sections of this Guide.

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# CAMOUFLAGE GOALS AND UTILITY

CAMOUFLAGE IN THE NORMAL VISUAL SPECTRUM

CAMOUFLAGE IN THE INFRARED SPECTRUM

SECTION 4

# CAMOUFLAGE GOALS AND UTILITY

## 4.1 GENERAL

After conducting the threat assessment, the general nature of the required countermeasures can be determined (i.e., the types of camouflage to be considered to reduce vulnerability and improve survivability of the system under study). These types of camouflage can be evaluated in general terms in order to arrive at minimum camouflage types and levels of protection to be achieved by detailed application of the camouflage techniques discussed in Section 5. The process of evaluation which produces these goals of protection by application of countermeasures is discussed in this section. From this evaluation, the protection to be gained and the corresponding improvements in system survival against the costs to achieve can be ascertained. In short, the camouflage countermeasure goals to be pursued are defined for further system development.

While the developer remains responsible for determining the appropriate countermeasure goals to survive and operate on the battlefield, the camouflage experts from the Countersurveillance, Deception and Topography Division of TROSCOM's U.S. Army Belvoir Research, Development and Engineering Center stand ready to assist in the process of establishing and achieving these goals. This assistance can range from minor consultation to major involvement depending on the needs and desires of the system developer.

The general nature of appropriate camouflage for any specific system is determined by the complete threat assessment described above. However, the determination of the following questions remain?

- How much camouflage is required?
- What cost is appropriate?
- How is worth to be judged?

While it is generally intuitively understood and conceded that camouflage has military worth, measuring the specific value and relating that to measurable performance factors is far from an easy task. Merely identifying a specific surveillance threat does not automatically trigger development of a countermeasure. Indeed, the cost and performance of a prospective countermeasure must be weighed against the effect it has on the operational capability of the system in order to best balance resource expenditures with improved performance/survivability. The method of identifying appropriate camouflage countermeasures is portrayed in Figure 4-1. The primary

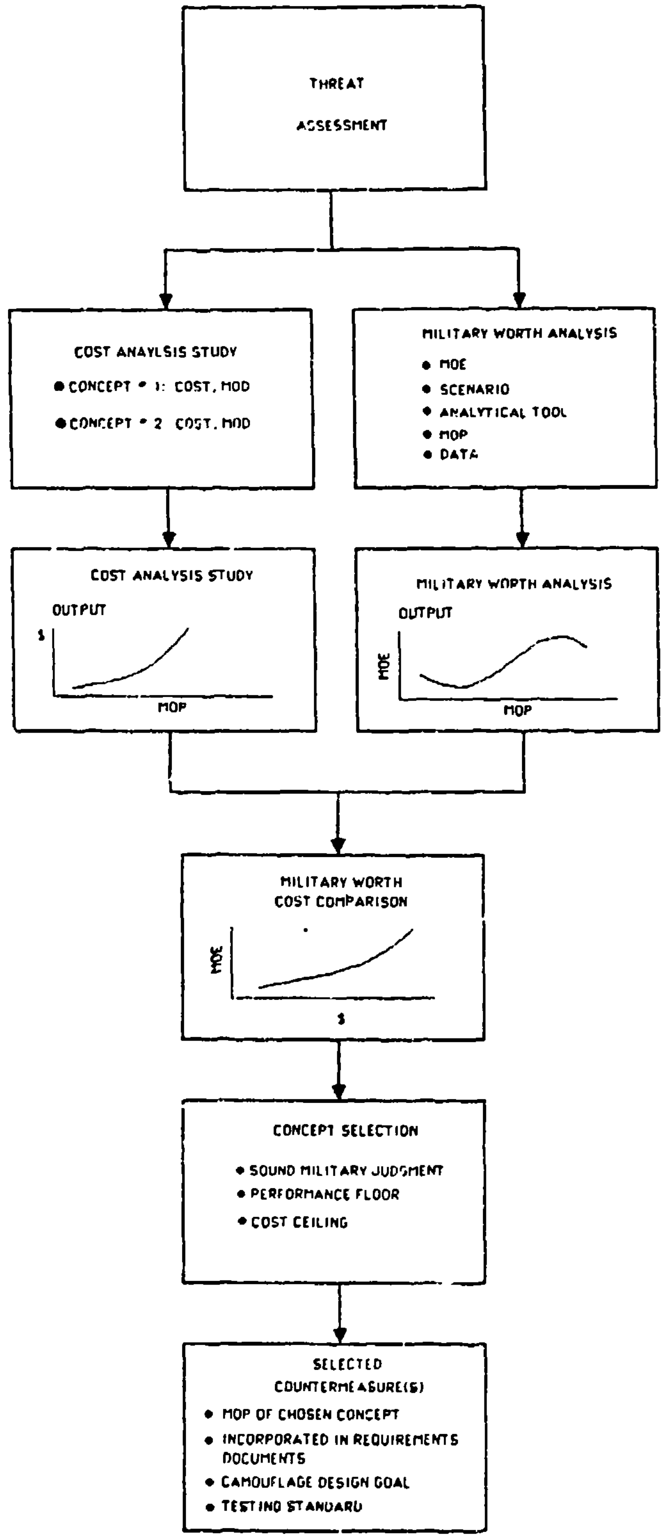


Figure 4-1. Countermeasure Determination Process.

process in this method is the military worth analysis. Also of significant consideration are the cost and performance trade-offs involved. These factors will be discussed in subsequent paragraphs.

## 4.2 DEVELOPMENT OF CAMOUFLAGE GOALS

In order to define camouflage goals for a critical or sensitive item/system, a functional analysis is often undertaken to provide the underpinnings for specifying performance and design objectives. A functional analysis relates mission characteristics, operational constraints and threat to the desired goals.

As a starting point, the requirements developer begins by translating the objectives of camouflage concerned with confusing, misleading, evading, hiding or negating enemy responses into conceptions and statements of what the item/system must do or exhibit in order to comply. The camouflage objectives are met by achieving one or more of the following conditions/situations:

1) Defeating enemy surveillance (systems/sensors).

2) Negating enemy target acquisition (systems/sensors) by confusing/eliminating signatures.

3) Extending items/systems lifetimes by reducing or diluting hostile encounters.

4) Diverting effective employment of target engagement systems.

5) Degrading utilization of target engagement systems.

The performance and design goals for camouflage items/systems evolve from considerations of the best means to counter the enemy threats/response as listed above. To accomplish this feat, the requirements generator must strive to follow guidelines and implement responses similar to those listed below:

1) Minimize logistics burdens.

2) Cause cost of camouflage to be order of magnitude less expensive than enemy response.

3) Limit burden/hindrance to accomplishment of mission objectives.

4) Withstand simple or easy methods to negate selected camouflage items/ systems.

5) Expedite movement of camouflage assets, consistent with mission objectives.

6) Tailor camouflage response to applications/needs.

7) Provide robust, reusable items/systems without compromising mission objectives.

8) Seek expendable, inexpensive, effective camouflage initiatives.

In setting out to define the camouflage goals for new items/systems, the requirements generator and the developer must be mindful of the following existing limitations and potential problem areas:

1) Current approaches are acceptable for some types of threats and conditions.

2) Camouflage is usually selected to counter the most frequent or important threat according to engagement or observation range, type of encountered sensors, conditions of weather/environment and activity of item or system.

3) Future threats are becoming more difficult to counter due to advances in data processing, fusion of information, frequency of observation, etc.

4) New camouflage initiatives and technological advances are continuing to emerge or are under development for countering the enemy threats and need to be folded into the selected responses.

5) Criteria must be established for defining what level of performance is necessary to counter the most pressing/likely threats to mission accomplishment.

Indications of camouflage performance goals must relate to what amount of emission by frequency spectrum is permissible before detection or identification can occur from various types of sensors at selected ranges, typical of engagement or encounter situations. In formulating this criteria, the requirements generator and equipment developer must collaborate to define the expected backgrounds, the signatures inherent in the equipment operation, and the techniques and technologies available to negate the expected threat sets. As an example, the camouflage goal might be stated as prevent the detection of an M1 tank at 5 km from an enemy forward observer using aided visual means in a thinly wooded area in western Europe.

## 4.3 MILITARY WORTH ANALYSIS

With the establishment of camouflage requirements or goals, the developer is now ready to make choices based upon military worth. This analysis centers about an evaluation of the capability of proposed camouflage measures (options) to meet mission objectives postulated for the items/systems as well as the operational effectiveness of a force employing them.

### 4.3.1 Elements of Analysis.

There are five essential elements in a military worth analysis. These are: data, measures of performance (MOP), scenarios, analytical tools, and measures of effectiveness (MOE). Figure 4-2 shows the relationships of these elements in a military worth analysis. Each of these will be discussed in further detail below.

4.3.1.1 Levels of Evaluation. The concept of differing levels of evaluation of the factors involved is helpful for understanding the process of analysis. Figure 4-3 shows the varying levels of these factors and how they are related to evaluation of camouflage options and the determination of their worth to battlefield operations. Note that each is related in a logical hierarchy with the factors shown associated with each level. Obviously, the most difficult connection is between Levels II and III, and this is the purpose of the military worth analysis.

4.3.1.2 Data. At the lowest level in the hierarchy are the details of concern primarily to the technician. For camouflage, these are the data stated in terms of sensory variables that describe the system and its detectability in its environment. In order for this data to be useful in the analysis, it must be translated into meaningful terms relating to system performance. This translation, while difficult, is possible based on understanding the threat, the sensors involved, and their characteristics.

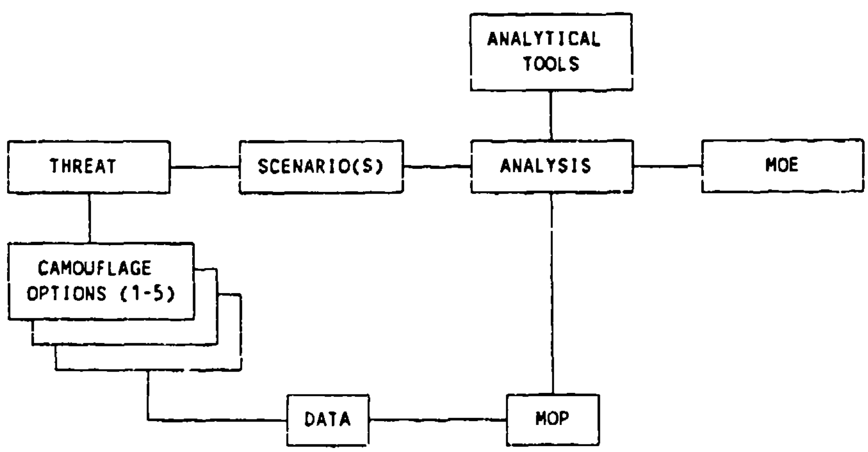


Figure 4-2. Military Worth Analysis.

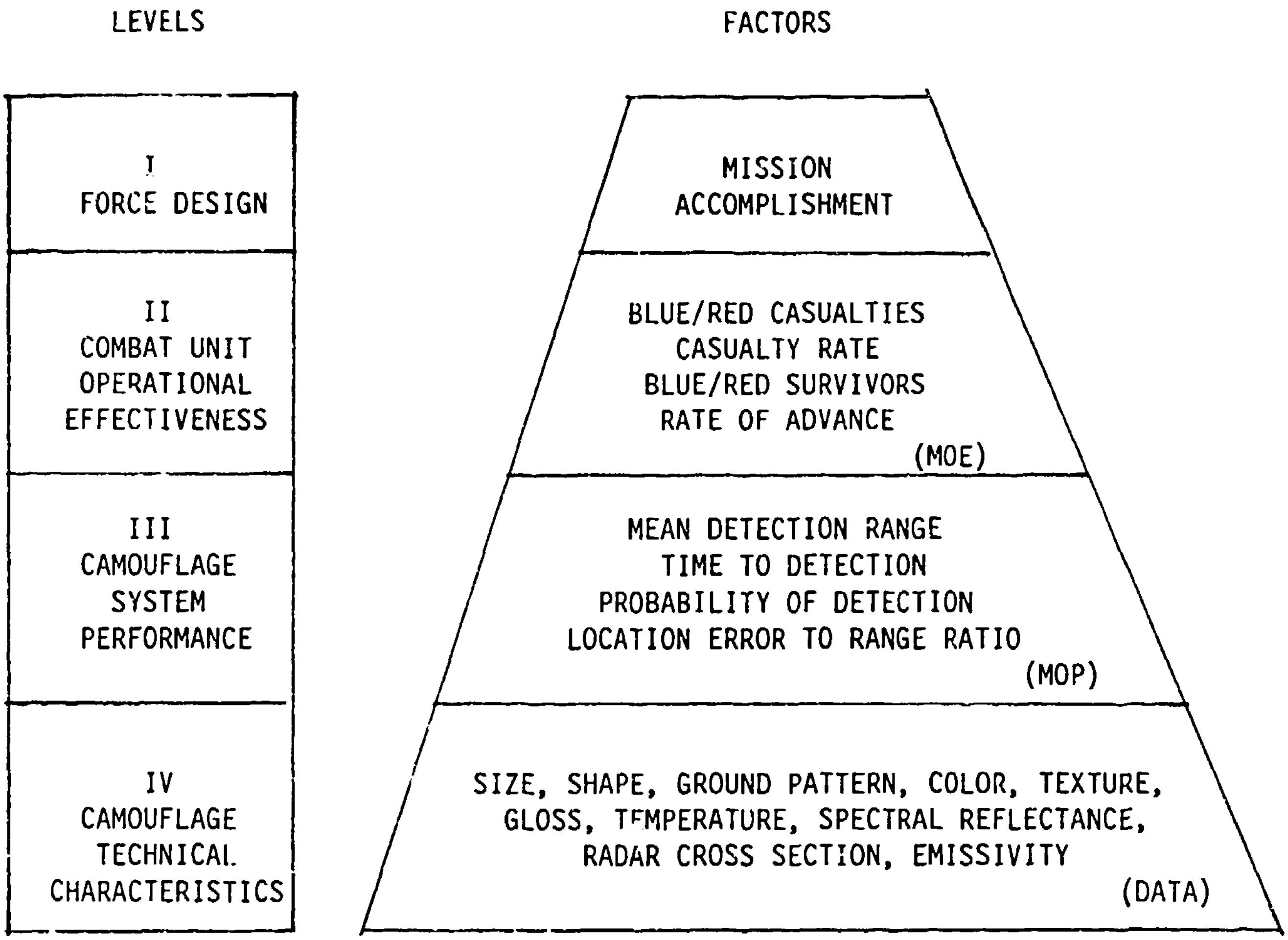


Figure 4-3. Levels of Evaluation.

4.3.1.3 Measures of Performance (MOP). Level III describes the system performance. These factors are measurable, given the proper environment, but they can also be derived from the data described in Level IV. MOP are stated in terms of system performance that are meaningful to both the camouflage system and the analysis being conducted. MOP are typically given in terms of time and/or range to detection, probability of detection, or ratio of location error to range. These factors can directly affect the outcome of an engagement analysis, which is the object of the process. These factors represent input and the process produces the output.

4.3.1.4 Scenarios. A standard analytical technique used in analytic evaluations is to postulate appropriate typical engagements that will exercise the variables being evaluated in settings closely approximating the anticipated employment of the system. Typically, they describe representative force structures and dispositions of opposing sides, the terrain, weather, tactics employed and missions pursued. The scenario should exercise the options being evaluated, and permit a range of outcomes to allow comparative evaluation.

4.3.1.5 Analytic Tools. The scenario is exercised by use of a combat simulation which produces the outcome necessary for evaluation. These simulations are typically models employed by computer to predict combat outcomes from given input conditions. While not all models are computer simulations, they are the most widely used. The model exercises the selected scenario and produces an outcome which can be related back to the input conditions. The outcome is stated in terms of measures of effectiveness (MOE). Since the model replicates a cause and effect relationship, it is possible to relate specific results (MOE) to specific input conditions (MOP). This is the object of the analysis, since it provides the link between Level III and Level II in the evaluation hierarchy of Figure 4-3. Combat models may be selected from the following types described below, depending on the specific system under evaluation and the battlefield characteristics examined.

- Analytical models - mathematical models which describe limited aspects of the system. Typically run on a desktop computer, these are usually available to the system developer for quick analysis of his system. Results are normally given in expected values.

- Deterministic models - these are more extensive models, employing terrain and time steps in model play. These are also expected value models. Results are reproducible but difficult to interpret since results contain fractional attrition values.

- Probabilistic models - these models employ probabilities and select a single outcome per play. Use of these models requires many replications to determine the most likely outcome for a single input condition, but results are easier to understand.

- War games - this term is used for simulating larger aggregations of forces where many variables are employed. Generally, the larger the force evaluated, the longer the simulation must run to achieve the outcome and the less influence a single factor will have on the outcome.

- Operational exercise - while more realistic, use of actual decision makers (man-in-the-loop) makes these simulations non-replicable and therefore not used in military worth evaluations.

Generally, the above model types are related as shown in Figure 4-4.

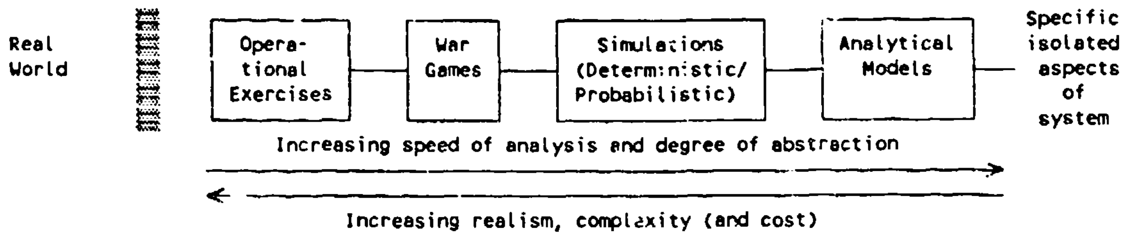


Figure 4-4. The Spectrum of Models.

Some examples of these models are shown in Table 4-1.

4.3.1.6 Measures of Effectiveness (MOE). These are the outcome of the analysis, which show the impact of the camouflage options employed, stated in terms that are meaningful to the military engagement success or failure. Typically, MOE are stated in terms of loss exchange ratios, rates of advance, casualty rates, Blue/Red survivor ratios. When these results are related to the input conditions describing a specific camouflage option, relationships can be developed such as that shown in Figure 4-5.

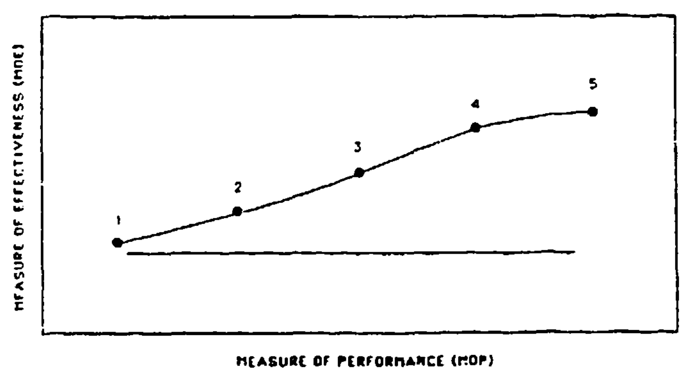


Figure 4-5. Example of Military Worth Analysis Results.

It is possible to develop the relationship between MOP and MOE parametrically if it is not known directly or absolutely. For example, if it is desirable to establish the best of several camouflage options, it may be possible to establish the relative merit among the several options without knowing the exact relationship of any of them. This technique will very likely save time and money in analysis and provide the desired result.

| MODEL | MODEL FEATURES | | | |
|---|---|---|---|---|
| | INPUT DATA | CALCULATIONS | OUTPUT DATA | APPLICATION |
| Deep Target Acquisition Model | ■ Scenario dependent parameters (hours) of daylight, target types, etc.)<br>■ Sensor specifications and performance (sensor types, capabilities, etc.)<br>■ Platform performance (platform characteristics, capabilities, etc.)<br>■ Target signatures (signature types, strategies, etc.)<br>■ Operational data (processing times, target movement profiles, etc.) | Perform deterministic calculation of instantaneous rates representing expected fraction of targets acquired that will remain in position until the time of attack, and average number of targets that have been acquired and could have been targeted | ■ Expected fraction of targets acquired as function of time<br>■ Expected fraction of targets remaining in position until attack<br>■ Average number of targets both acquired and possible to attack | Assesses capabilty of penetrating deep behind FLOT to locate and identify targets for subsequent attack. |
| COMWTH II<br>Deterministic simulation of major battlefield factors that affect target detection evaluation and engagement process. | ■ Battlefield Environment/Deployment<br>■ Target Descriptions<br>■ Sensor Descriptions<br>■ Doctrinal Considerations<br>■ Tactical Situation<br>■ Munitions Effectiveness | ■ Which particular targets will be detected?<br>■ Which targets will be acquired?<br>■ Which targets will be attacked?<br>■ Damage to targets attacked? | ■ The affects of enemy sensors, weapons and tactics on U.S. forces.<br>■ The affects of U.S. sensors, weapons and tactics on enemy forces. | ■ Assess the vulnerability of friendly camouflaged items to enemy reconnaissance and target acquisition sensors.<br>■ Determine camouflage design goals.<br>■ Conduct parametric analysis to determine the optimum method and amount to degrade enemy sensor performance to enhance U.S. equipment survivability. |
| CASTFOREM<br>Probabilistic simulation/ war game used to evaluate effectiveness of force capabilities | ■ Terrain description parameters<br>■ Weapon effects data<br>■ Unit orders<br>■ Combat support and combat service support equipment data<br>■ Commo data/network structures<br>■ Environmental data<br>■ Decision tables<br>■ Organizational structures<br>■ Personnel description parameters | Performs combat simulation in time steps using voluminous decision tables, generates necessary orders, reports. Has some capability to handle event-generated effects. | Sequenced events based on force-on-force play to give outcome in terms of losses to both sides, force movement, maneuver results. Camouflage effects handled as changes to input data, output depends on input. | Used by Army as most detailed simulation of force-on-force combat. Results have full credence in Army. Because of large number of variables, will likely show little effect of camouflage-generated changes in overall results. |

Table 4-1. Specific Illustrative Models.

Another parametric approach would be that of determining the MOE required to alter the outcome of a simulation and then work back through the simulation to find the MOP necessary to make it occur. For example, for engagement by fire of a target, the target must first be acquired. If camouflage techniques can be applied to reduce the probability of detection significantly, the probability of engagement goes down correspondingly, and the probability of survival of the target goes up. This then will establish the MOP goal to be achieved by the camouflage option.

## 4.4 INDICATORS OF MILITARY WORTH

At this stage, a look at several illustrations of how camouflage may contribute to military worth are instructive. This series of presentations will show the effects of camouflage on range at which detection and identification occur, as well as the consequences of changes in probability of acquisition on engagement outcomes, resources expended, and mission lifetime.

### 4.4.1 Implications of Camouflage on Target Acquisition Range.

Based upon the theory of camouflage against visual observation and characteristics of clutter on the battlefield as presented in Appendix A, Table 4-2 shows how the application of camouflage changes the range for detection, recognition and identification in the presence of no, low and moderate clutter. In this example, the target is 2 $m^2$ and lines are added to the surface to break up the visual image into segments (pages A-2 through A-5 describe this process in further detail).

An examination of Table 4-2 reveals that without clutter and camouflage, a 2 $m^2$ target can be detected at 8 km with unaided visual means. Of course, line of sight and earth curvature prevent this from occurring unless an airborne platform or vantage point for observation is available. In defense, where some part of the target may be in defilade, this same target might not be detected at stand-off beyond 2 km due to the presence of camouflage and moderate background clutter.

This detection range can be reduced by the use of aided visual means (like binoculars). However, the user of such aided visual means is hampered by the large amount of time necessary to search the suspected target area (especially as other critical tasks are also being performed). For recognition and identification, similar results can be observed in this table.

Table 4-2. Representative Maximum Ranges for Target Acquisition

| No Clutter No Camouflage | Low Clutter No Camouflage | Moderate Clutter With Camouflage | Moderate Clutter With Camouflage — Conservative Estimate for: Defense | Moderate Clutter With Camouflage — Conservative Estimate for: Attack |
|---|---|---|---|---|
| **Detection** | | | | |
| 1.00 Lines<br>8.00 km | 2.00 Lines<br>4.00 km | 4.00 Lines<br>2.00 km | 4.0 Lines<br>2.00 km | 6.00 Lines<br>1.33 km |
| **Recognition** | | | | |
| 7.0 Lines<br>1.14 km | 8.0 Lines<br>1.00 km | 10.0 Lines<br>0.80 km | 0.80 km | 12.0 Lines<br>0.67 km |
| **Identification** | | | | |
| 11.0 Lines<br>.68 km | 12.8 Lines<br>.63 km | 14.8 Lines<br>.54 km | 14.8 Lines<br>.54 km | 16.8 Lines<br>.47 km |

### 4.4.2 Implications of Camouflage on Engagement Outcomes.

In the most elemental situations where opposing soldiers or weapons are involved in a duel by searching for targets to shoot, the use of camouflage can provide an advantage by degrading the capability of the opposing sides to detect and "shoot first." The capability to shoot first" can be reflected as a measure of the possibility of detection (and possibly recognition) by each side at a potential engagement range.

Figure 4-6 portrays the outcome of a duel as a function of the detection and kill capability of opposing sides in a single exchange condition. For this analysis, the enemy side is assumed to have a single shot kill probability ($SSP_{K/A}$) given acquisition of 0.5 and the total capability of shooting first by both sides is considered to be equal to a value of one. The combinational effects of high $P_K$ and $P_D$ (depicting capability of shooting first) on a favorable outcome of the duel are apparent. At high kill values of $SSP_K$ (say 0.8) for the friendly side, changing the $P_D$ from a value of 0.2 to 0.7 of the enemy results in a favorable outcome (killing the enemy target) from a value of about 0.55 to 0.75 (i.e., a 50% improvement in favorable outcome).

Consider the case of an air defense vehicle (AD) utilizing guns as armament and facing an attack by opposing element utilizing wire-guided missiles (refer to Figure 4-7). It can be shown that the AD has a considerable advantage if he can defer the opening of a duel until the opponent (either an armed helicopter or an infantry fighting ground vehicle) is closer than 1000 meters. The wire-guided armament is designed to have an advantage at the extreme ranges of its effectiveness (2000 m to 4000 m),

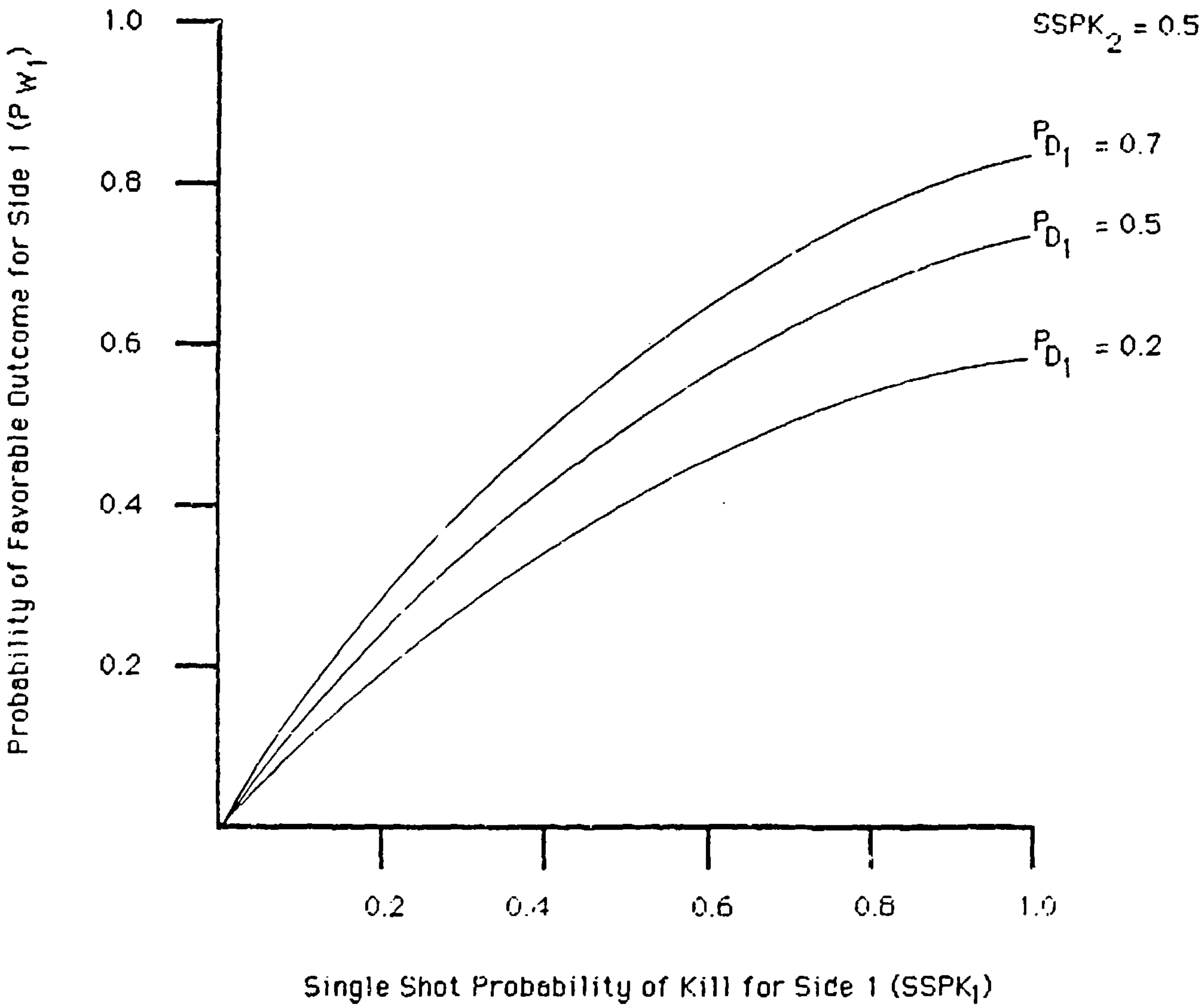


Figure 4-6. Effect of Shooting First on Single Exchange Outcome.

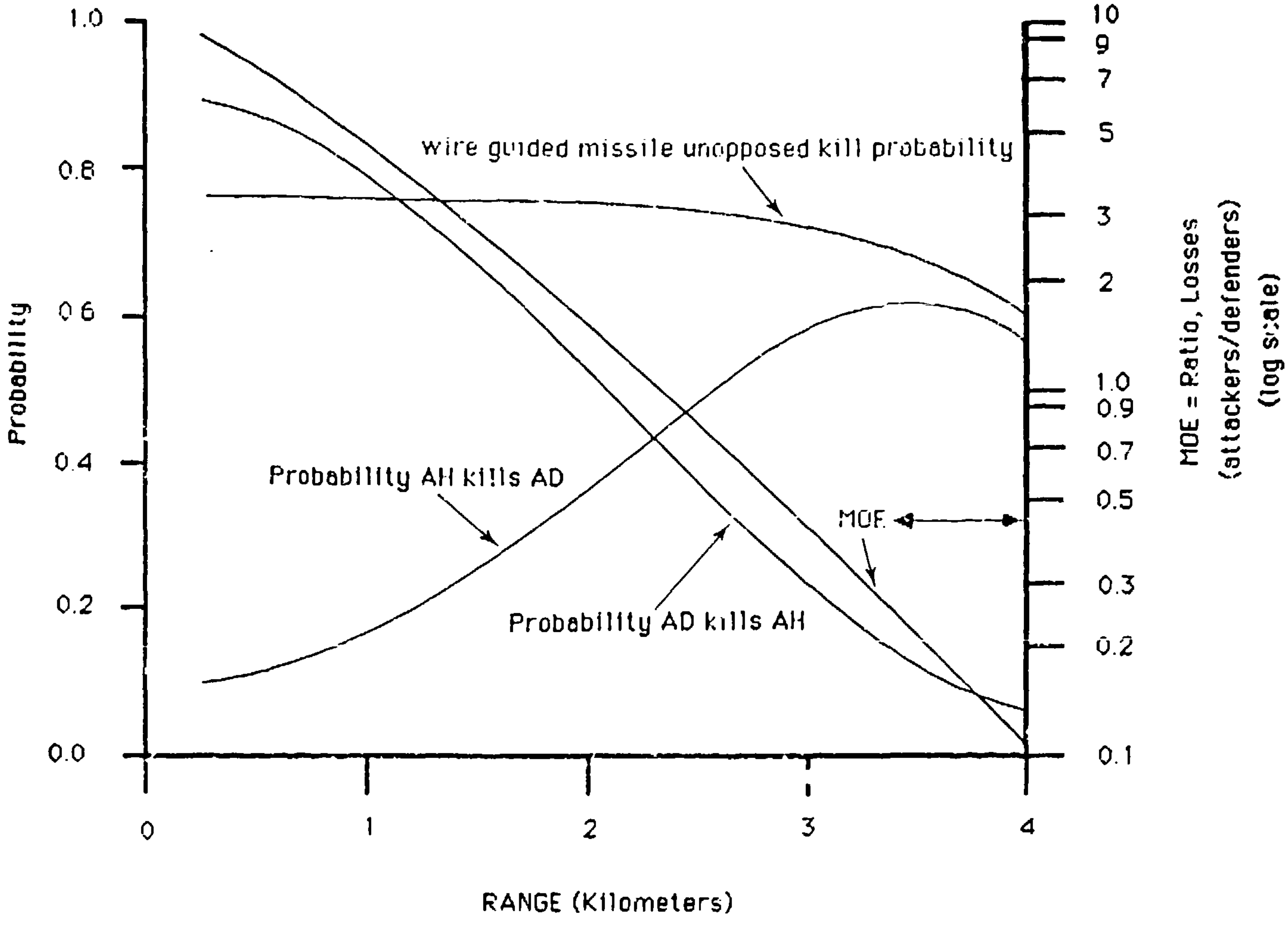


Figure 4-7. Typical Curves for One-on-One Duel Between AH and AD.

where it is outside the effective range of gun/projectile firing armament. Figure 4-7 shows the characteristic expected outcome of duels between an armed helicopter (AH) that pops up from behind a low lying defilade undulation in terrain, acquires the AD as a target, fires, and remains exposed while it guides its missile to the defended target (the AD). The AD alert in an inactive state becomes active, acquires the AH on the radar, clears its guns and opens fire in short bursts of fire. Figure 4-7 shows the exchange ratios expected (on the average of many such engagements) as a function of range (curve giving MOE, on log scale). At long ranges (2000 m to 4000 m), the AH has the advantage. From 1000 m to 2000 m, it is about even; below 1000 m, the AD has a decided advantage.

Obviously, the tactic of the AD is to remain inactive until the range to an opponent has decreased to less than 1000 m. He cannot have this option available to him unless the maximum range for target acquisition of the AD by the AH is reduced to less than the desired 1000 m, and preferably below 500 m. There is here a tangible role for camouflage. If, using camouflage, the AD can reduce the probability of detection by the AH to between 1000 m and 500 m, the likely outcome of the engagement (MOE) will favor the AD.

4.4.3 Implications of Camouflage on Resources and Missions.

Camouflage can also be used to conceal or mis-inform the other side on the central location of a unit, or hide targets from observation, or extend the mission lifetime of an item/system. Examples of each of these applications are portrayed below.

For the case where the enemy is delivering indirect (artillery) fires into a suspected area, the number of rounds to produce required damage is greatly influenced by the capability to locate the center of the target. Camouflage of targets can aid in causing the enemy to select a poor aimpoint. Poor target location errors can occur by hiding boundary lines or creating erroneous impressions of the center of activity, or misrepresenting the location of the highest density of combat materiel. The consequences of target location errors (TLE) on required artillery rounds against typical combat targets are displayed in Figure 4-8. For example, an increase in TLE of 100 meters will cause the enemy to fire from 75 to 175% more rounds to achieve desired damage levels, depending upon target hardness and engagement conditions (range, damage objectives, target radius, type of round, etc.). Softer targets benefit more from large TLE as the probability of kill by a single unguided artillery round on hard targets is already low (almost a random chance of intercept is a statistical representation of the event).

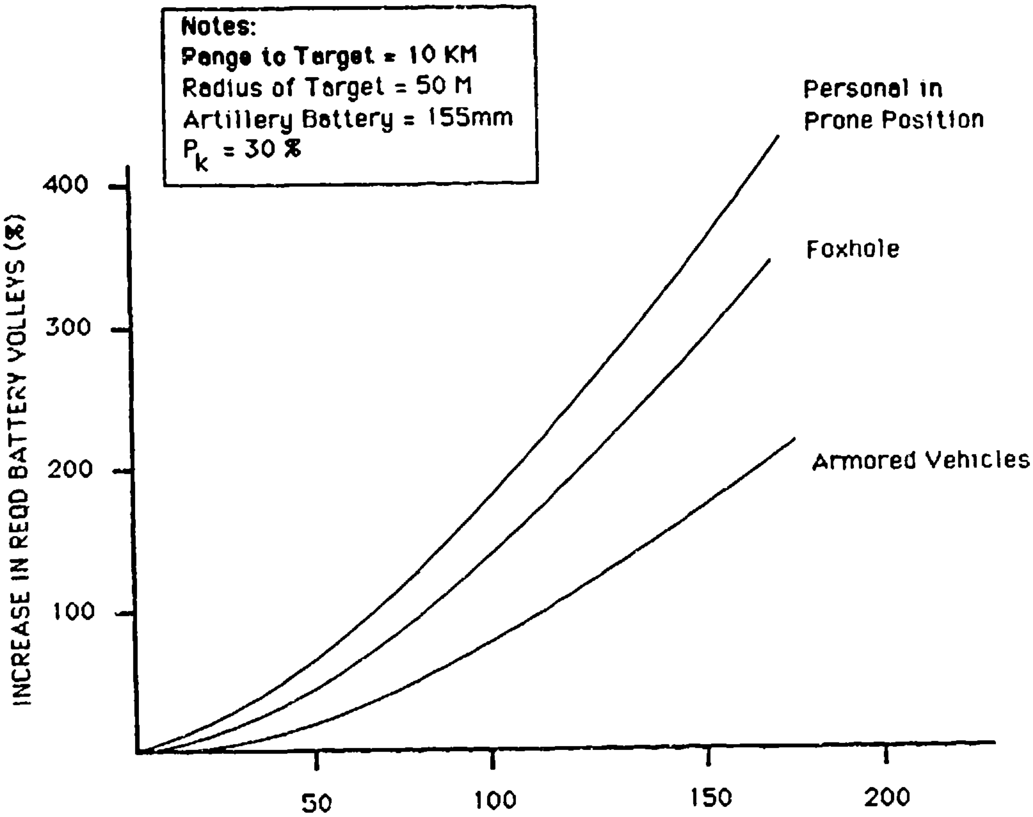


Figure 4-8. Effect of Camouflage on required Artillery Batteries.

Anotner case involving the value of camouflage to confuse the enemy in the selection of a target can accrue when decoys are used to provide false targets and camouflage is applied to hide the real targets. Such a situation is depicted in Figure 4-9. The implications of camouflage combined with decoys on reduction of losses to enemy armed reconnaissance forces are shown as a function of number of poor choices in target selection and attrition rates. In this illustration, the reconnaissance force is assumed to have a $P_K$ of 0.5, given a real target is selected for attack. Even at low attrition rates of 5%, the attacker loses over 50% of the reconnaissance force if 4 false targets are chosen improperly or the target center is improperly located to cause 4 misdirected attacks.

Figure 4-10 shows how the number of successful mission and actions for an item/system can change as a function of enemy target acquisition (TA) and probability of kill given acquisition. In this simple illustration, the number of successful operations are defined by the ability to operate without being acquired and killed and each event (mission) is considered to be independent. This condition often exists on the large battlefield where large numbers of targets, sensors and weapons are present. Of course, sometimes an acquired target is pursued until killed so the inference reflected in this figure is not appropriate. At high kill $P_K$'s, the value of limiting enemy $P_A$ is more important in terms of number of successful missions likely to be performed. As

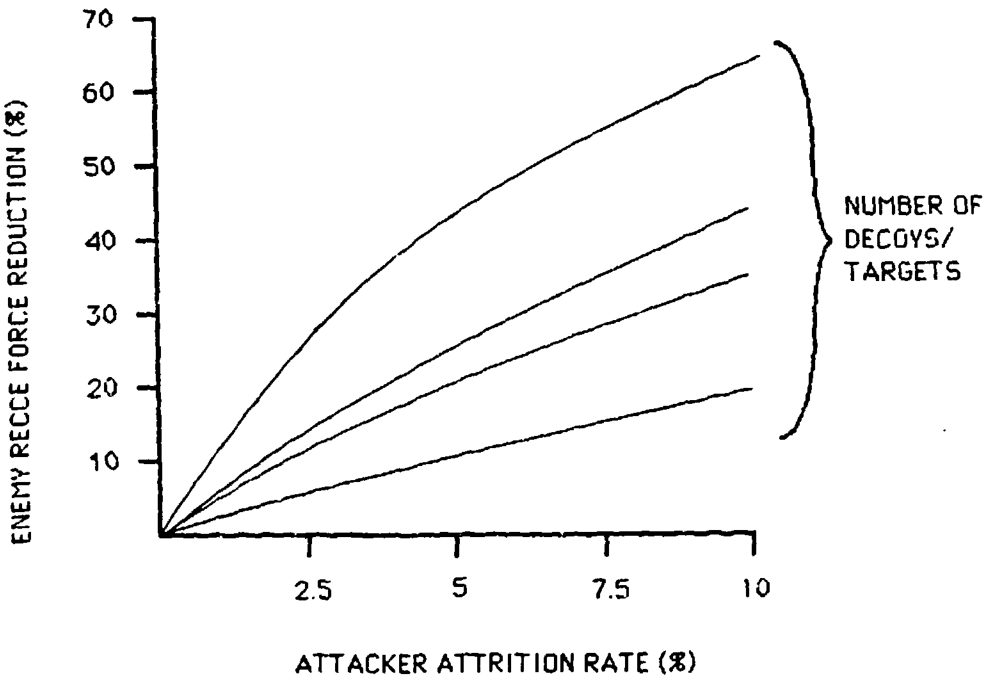


Figure 4-9. Effects of Deception/Camouflage on Attacker Force Requirements.

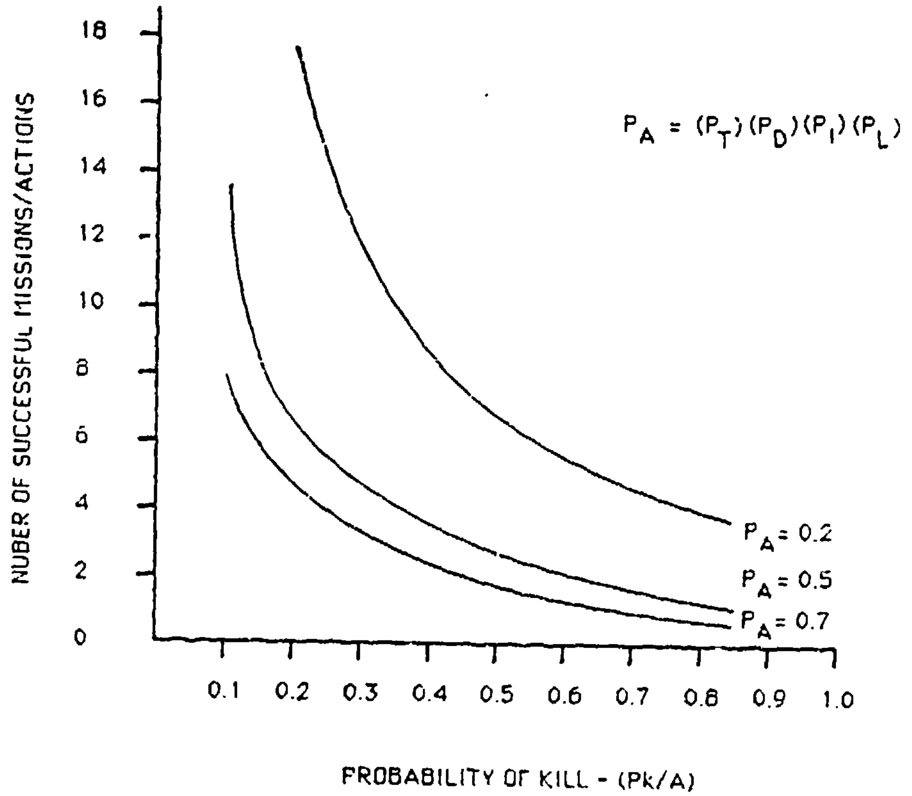


Figure 4-10. Effects of Camouflage on Mission Success in Engagement Conflict Zones.

an example, Figure 4-10 shows that changing the $P_A$ from 0.7 down to 0.2 increases the number of successful mission by a factor of 4 at a $P_{K/A}$ of 0.8 and an improvement in successful missions by a factor of about 3 is achieved at a $P_{K/A}$ of 0.3.

## 4.5 OTHER CONSIDERATIONS

### 4.5.1 Cost.

Another variable of concern, but not included in military worth analysis, is the relative cost associated with each of the camouflage options considered. Just as the military worth analysis developed the MOE associated with specific MOP, so also the cost of each option can be established and a chart similar to Figure 4-11 can be developed.

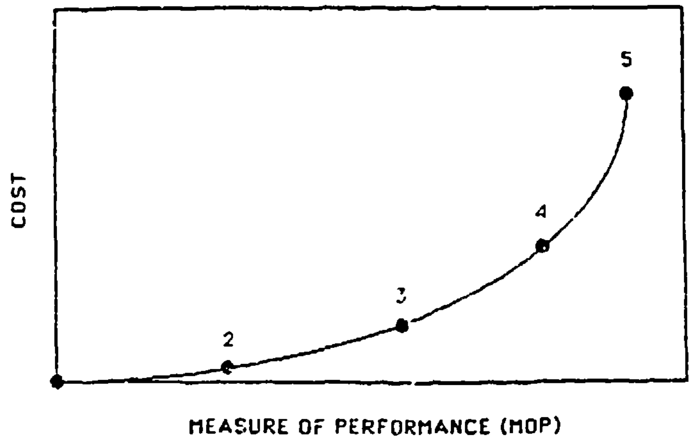


Figure 4-11. Cost of Various MOP Levels.

### 4.5.2 Performance Limitations.

In addition to monetary costs, there is a possibility of performance penalties associated with certain camouflage options. For example, if we assume that an operating system in an active role is emitting something detectible while performing its function (shells, communications transmissions, vibrations, light, heat), the benefit acquired from camouflage is minimal. However, when emissions cease, the system can go into either an inactive or a passive status. Inactive means ready for action, with systems operating and pressures and temperatures at the ready levels. These can present detectible signatures that may need to be camouflaged.

Elements in a passive status are not in an alert status. If they have defense armaments, they require more time to bring their element to a state of battle readiness. On the other hand, while in a passive mode, they presumably are not emitting radiation that may be associated with motor-generators, petroleum fueled motors, or heat generated by function-ready operating conditions. That is, they will not be generating the quantities of heat needed to maintain a battle-ready inactive condition. They trade, then, decreased vulnerability to detection for the liability associated with the increased time needed to achieve a battle-ready/active status. The requirements for camouflage are shifted away from the problems associated with IR detection. Since such elements will normally be equipped with heat dissipation deflection and IR shields for protection from IR acquisition when in the inactive mode, it remains the local commander's decision and initiative whether/when to permit his elements to go into a passive mode and when to require them to maintain an inactive status. The basic design problems for the passive mode are subsumed under protection of the inactive mode.

If the commander elects to employ camouflage in order to maintain an inactive state of readiness, there may be a penalty associated with the time necessary to bring his system to an active status, such as removing nets, shields, etc. in order to gain its full range of function. This represents a cost in terms of performance limitation that he must weigh against the protection benefits gained.

## 4.6 SELECTION OF COUNTERMEASURE OPTIONS

When the result of the military worth analysis (MOE versus MOP) and the cost evaluation (cost versus MOP) are combined, a cost-effectiveness relationship similar to the one shown in Figure 4-12 can be developed.

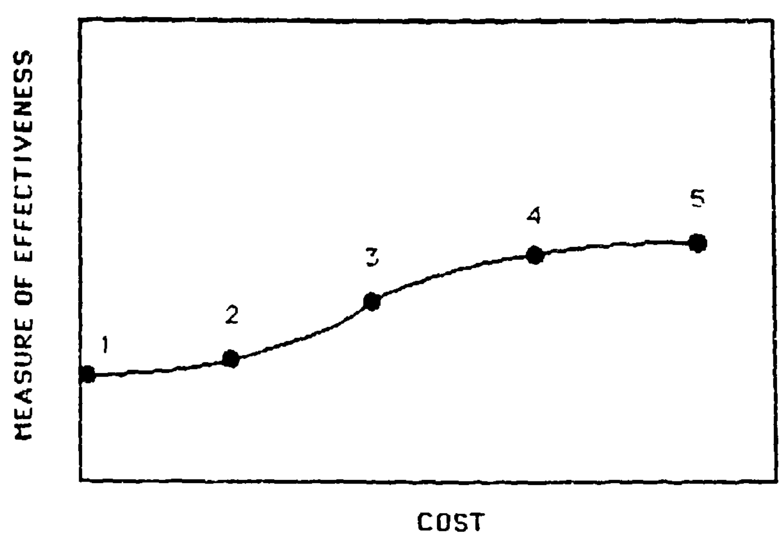


Figure 4-12. Example of Cost Effectiveness Analysis Results.

This relationship should permit the decision maker to reach sound conclusions on the camouflage option that best meets his requirements. Sound military judgement is required to determine which is the best combination for his system.

The camouflage concept selected thus becomes the countermeasure goal sought. The goal provides the developer with the specific criteria (MOP) he needs to establish camouflage requirements in his requirements documents (O&O Plan, ROC, COEA, etc.). Further, it establishes his design goals and tells when he must supplement built-in measures with add-on measures. It also provides the standards he needs to test for in the test and evaluation cycle (see Section 6), in performance terms.

## 4.7 REFERENCES


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# CAMOUFLAGE POSTURE AND APPLICATIONS

## M-1 TANK IN HULL DEFILADE
(AN INEXPENSIVE TWO-DIMENSIONAL DECOY)

# SECTION 5

# CAMOUFLAGE POSTURE AND APPLICATIONS

The purpose of this section of the Camouflage Guide is to examine the technical basis for camouflage and illustrate concepts and applications contributing to various camouflage postures.

## 5.1 NATURE OF CAMOUFLAGE

Camouflage attempts to deny or misrepresent objects, signatures, signals, or other evidence to enemy observation. It is normally achieved through hiding, blending, disguising and decoys. It is, therefore, a form of counterintelligence. Camouflage includes the application of passive measures to reduce target perceptibility to surveillance (Reference 1).

The difference between camouflage and other countermeasures in general is that camouflage does not deny the actual use of remote sensing means or RSTA systems, or destructively interfere with their internal operation. Camouflage decoying techniques depend upon normal RSTA observations to transmit misleading information to an enemy in order to conceal truth. Camouflage deals directly with the information which remote sensors and observers process.

Effective camouflage is a result of camouflage consciousness in a number of areas. This is especially true when applying camouflage to operational characteristics or to items/systems in the field. Camouflage consciousness is the product of command emphasis, discipline, training, techniques and materiel. Failure in any one of these areas can dilute camouflage effectiveness. Concealment may be employed to increase item/system survivability by reducing the system's detectability and hence, its "hitability."

Concealment is also employed in combat to achieve surprise. The surprise may be with respect to an individual, an entire force, or intermediate units. Although the advantage (or military worth) of surprise cannot be directly or precisely quantified, most military tacticians recognize "surprise" as a favorable factor in the power relationship of an engagement.

When applied to camouflage, the term *passive* means that no attempt is made to destroy the observer. However, all passive countermeasures cannot be considered as camouflage. For example, certain passive countermeasures in the area of electronic warfare are not considered to be a part of camouflage. This is not only because of differences in intent, but also because of technology differences. Likewise, cryptography, a "passive" form of concealment is seldom considered as camouflage.

The word perceptibility is often used to indicate those characteristics, states, or quantities of an item/system (and its operation) which cause it to be detectable, identifiable, locatable and "hitable" through RSTA means. The purpose of camouflage is to change the perceptibility of an item/system.

5.1.1 Scientific Basis.

Interfaces between camouflage and RSTA threats involve the science of physics, psychophysics, and psychology (Reference 1). The phenomenon of energy transfer from energy sources to a target and eventually back to a sensor is governed by physical laws involving electromagnetic and mechanical energies and chemical dispersion. Psychophysics treats the mechanisms and limits of a human to process external energy variations as they impact sense organs (eyes, ears, etc.). The internal processing of energy variations impacting on transducer elements in modern remote sensing systems has much in common with psychophysics. Both relate to communications theory. The special fields of psychology that are concerned with camouflage are perception and the behavioral processes which affect awareness and identification.

One of the difficulties of camouflage design and evaluation is that camouflage encompasses physical and biological as well as behavioral sciences. Briefly, a description of the role of these sciences with respect to camouflage is useful in understanding the challenge of camouflage development.

5.1.1.1 Physics.

The laws of physics govern the energy exchanges by which military targets are detected and identified, obeying the principles of energy propagation, reflection, absorption, and emission (Figure 5-1) (Reference 1). The physical methods of energy exchange with which camouflage is concerned include electromagnetic, mechanical (sonic and seismic) and the processes of chemical dispersion. Some understanding of these methods is necessary so that the design and application of camouflage can successfully exploit, for concealment purposes, the energy exchange principles and the laws upon which sensors operate.

Camouflage is concerned with preventing, reducing, shielding, or otherwise controlling in direction and amplitude the energy emitted by and/or reflected from various materials. The medium through which the energy must travel to reach a sensor also affects the energy in various ways and this effect must be accounted for in the attenuation and refraction of the energy prior to reaching the sensor. For example, engine vibrations cause a flow of energy through the air in the form of waves. Variations in the air density, wind direction and speed, moisture and other impurities such as dust or smoke in the medium, and reflections from the ground and other objects all affect the nature and quantity of energy reaching a remote sensor.

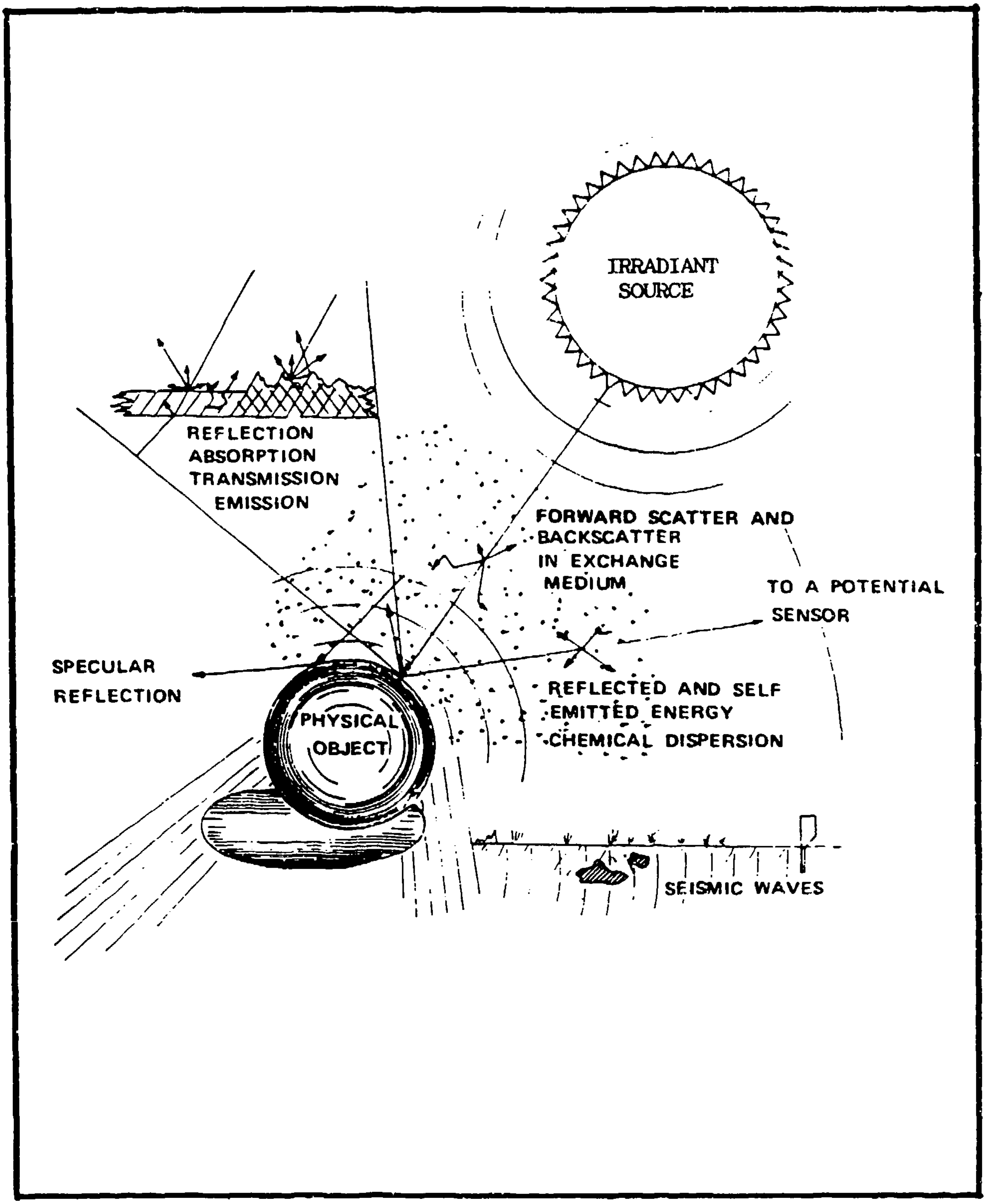


Figure 5-1. Physics.

Finally, a knowledge of the sensitivity and resolution of RSTA sensors is necessary to determine what levels of energy can and should be denied under given conditions. Sensitivities to both amplitude and wavelength is also an important concern. For example, the energy transmitted from a target might be shifted to a band of frequencies where the medium absorbs the energy or where the sensor is insensitive.

5.1.1.2 Psychophysics.

Psychophysics deals with problems common to physics and psychology. It can provide further knowledge of how to treat materiel in order to deny or confuse the data resulting from psychophysical processing. For example, human vision has certain resolution limits, contrast-discerning limits, and spectral response limits as does photography and many other sensor systems. Camouflage attempts to capitalize on the discrimination limits of the sensor systems by keeping perceptible data from the target below the contrast resolution and sensitivity thresholds of the sensor system.

5.1.1.3 Psychology.

Remotely sensed data entering the brain must be perceived by an awareness. The field of psychology called perception is concerned with the mental process of awareness and identification. Humans constantly receive so much information that nature has devised a filter system which treats most of it on an automatic or rejection basis. Only through a phenomenon called "attention" are things perceived in a state of awareness. This phenomenon involves a combination of two factors -- identity and motivation.

Identity as used here is a function of memory, or stored data, against which incoming data is compared as it is received to produce some level of recognition. In this context, camouflage functions by modifying the cues which are used to classify the signals and objects observed so that, by comparison to memory, they will be falsely classified. This is most easily achieved when the modified cues form an image or comprehension to an observer that is easily recognized and is considered benign. There is a very powerful need in humans for recognition and the mind will often fill in non-existing parts of an image or signal pattern to create a recognizable form or comprehension.

Motivation can be divided into instinctive reaction and purposeful intent. Subconscious defensive mechanisms are built into the human system so that, for example, rapid movement of a close object usually creates instant attention, awareness and apprehension as instinctive reactions. An example of intent is that of an image interpreter assigned to locate aircraft in photographs of a suspect area. The interpreter, in searching, will likely be unaware of most other items in the imagery. On the other hand, if he is given the task of searching the imagery for military objects, he will more likely be aware of all items that are not indigenous to the terrain being searched. In this context, camouflage always attempts to use disguises which are not likely to arouse fear or concern in the observer and thus call attention to themselves.

Where it is not feasible to present a disguise that appears to be part of indigenous terrain or background, the disguise should portray something benign or that represents a minimal threat to an enemy. Hence, tanks are made to appear as trucks, but not vice versa.

5.1.2 Tasks of RSTA Systems.

Intelligence on the battlefield is normally obtained by coupling an analysis of the data obtained from remote sensing means with general or background knowledge relative to a hostile force's overall capability and intent. In order for RSTA systems to accomplish their mission, three processes must occur (Reference 2):

- The sensing devices must be capable of discriminating differences between characteristics of the target and the environment in which the target is located -- and it must be able to display these differences.
- Some process, human or otherwise, must then detect these differences in the display.
- Finally, some form of intelligence must decide if these differences represent an object or activity of military interest.

5.1.3 Tasks of Camouflage.

Camouflage is primarily aimed at reducing detection as well as the levels of identification that can be derived from the data obtained through the RSTA systems by:

- Reducing threat contrast below levels at which sensor systems are incapable of discriminating or displaying,
- Reducing target contrasts to levels that cannot be detected on sensor system display, or
- Minimizing signatures or cues and thus deny or delay target identification.

Camouflage methods can be divided into two groups which reflect a two-phase concept of reducing perceptibility (Reference 3). The first group includes those methods and techniques which defeat the sensor by reducing target contrasts below levels at which sensor systems cannot discriminate. These methods are designed to defeat both the remote sensors and the psychophysical capabilities of the observers. They employ techniques which are based on knowledge of the sensitivity, frequency response, contrast levels, resolutions, edge discrimination, etc., of the remote sensors involved.

For example, assuming no physical obstruction to observation, a tank painted white observed against a green foliated background can be detected visually in a clear atmosphere during daylight at a range of several miles. By utilizing knowledge of the limits inherent in human visual capability, the detection range of the tank can be dramatically lowered by painting it a dark color (Figure 5-2).

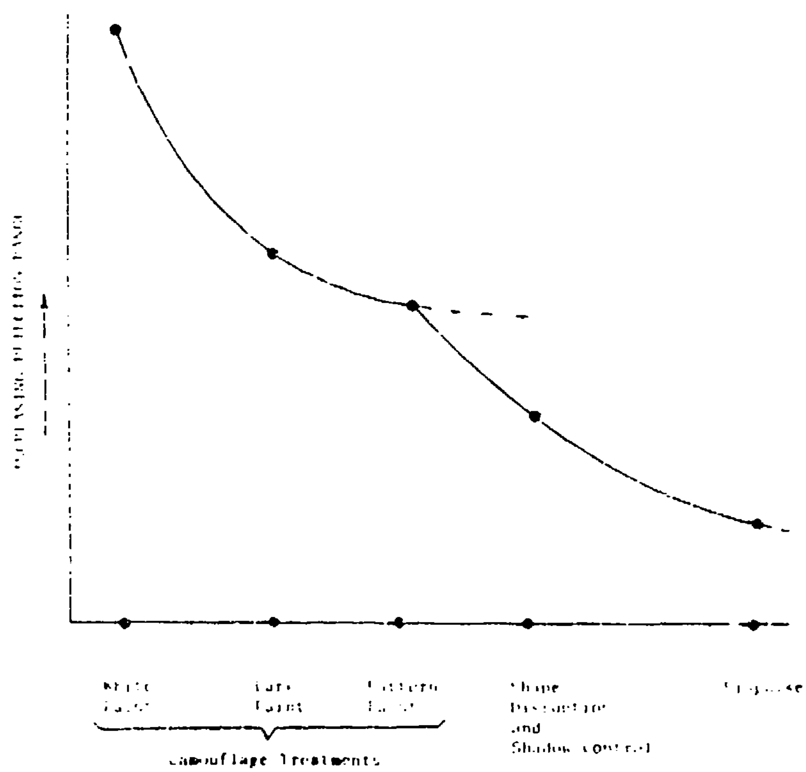

Figure 5-2. Tank Detection Range.

By further reducing the contrast and adding pattern painting to the tank, the detection range is again decreased. The detection range can be progressively diminished until a point is reached where no further amount of surface treatment will prevent detection. The inherent bulk of the item and shadows cast on itself and its background usually provide such strong cues that no surface treatment can prevent a high detection probability at close range. The addition, however, of shape disrupters and shadow casting materials often can provide reduced detection ranges, below those achievable with surface treatments alone, by altering the continuous and form-revealing shadows.

Another method of reducing perceptibility other than hiding or blending is illustrated by treating the same tank to appear as an element of the background (e.g., through application of disguise). The observer will likely fail to comprehend its presence even though it is in plain sight at close range.

A second group of camouflage methods begins with the hypothesis that under reduced range, multisensor use, and extended search time, the presence of nearly anything of a military nature will be detectable. Therefore, a major effort should be made to alter cues from which identifications can be made by enemy observers and homing devices.

The principle of perceptibility operates by making the tank appear to be an object which is not of importance to the observer (Reference 6). The observer's perceptive attention threshold is not crossed and the observer may not become aware of the disguised tank's presence. Consequently, camouflage must incorporate the broader concept that the awareness of truth must be confused or denied and not be satisfied by simply reducing the ability of RSTA to sense an item's presence.

This aspect of the camouflage activity, therefore, deals with defeat of the perception of targets and activities, not only by defeating the remote sensor itself, but by defeating the analysis and conscious awareness of what is observed or recorded through the sensor. This approach is useful for items/systems themselves, their ground pattern, operational procedures, and even their spoor (Reference 13).

Progressing one step further, inevitably there will be items/systems which by their nature, are not amenable to hiding, blending or disguise. Survivability and surprise potential for those items/systems can often be improved through denial of truth by the use of decoys or deceptive techniques which, if fielded with all necessary signatures, can create confusion and even draw fire on the decoy. The most effective use of decoys occurs when the decoy is a more attractive target than its archetype.

5.1.4 Sources (Types) of Camouflage.

The historic method of applying camouflage with field troops using local materials or standardized camouflage materials was appropriate in past times. However, now it is inadequate to counter many of today's surveillance and target acquisition capabilities. As the lethality and accuracy of weapons increases, the ability to remain concealed becomes more important to survivability and mission success.

Many RSTA systems now depend on signatures emanating form opposing systems which are beyond the recognition of the employing troops. Effective suppression or disguise of target signatures must be dealt with by technical personnel. It is axiomatic that the earlier in the life cycle the signature cue problems are identified, the more likely that practical solutions will be found and applied. This has lead to the concept of "built-in" camouflage (Reference 1).

5.1.4.1 Built-In Camouflage.

The term "built-in" is meant to include all materiel and procedures designed into the item/system. This may include attachments or accommodations for the use of standardized camouflage materiel such as the standard modular screening system. However, there are likely to be many design features or materials used which will not be recognizable or inventoried as "camouflage materiel." The important point is that the perceptibility of the item/system will be within militarily useful limits when it is fielded. Further, this built-in concept includes the employment, doctrine, training, and operational standard operating procedure designations required to permit maximum utilization in all types of terrain worldwide and the proper exploitation of terrain to further minimize detection and "hitability."

The best qualified person to determine built-in camouflage for an item/system is the developer. A few camouflage possibilities which the developer should consider are:

- Thermal shielding, insulation or dissipation.
- Flash suppressors.
- Smokeless propellant.
- Silencers, mufflers, sound deadening panels.
- Oblique metal surfaces.
- Recessed or covered lights and optics.
- Low silhouette.
- Hinged windshields.
- Fabric with textured camouflage patterns imprinted.
- Packaging materials printed with camouflage colors.

Built-in camouflage which is retrofitted to existing equipment may be thought of as "add-on" camouflage. This could include repainting if the equipment were painted at the factory, or devices such as flash suppressors, mufflers, RAM, etc. that are added later.

### 5.1.4.2 Operational Camouflage.

Operational camouflage is concerned more with elements of training and discipline than with materials. Operational camouflage can be responsive to a local situation with respect to tactics, position and background and may include the proper use of natural cover and shadow, concealment of tracks, proper disposal of litter, blackouts, the control of noise and dust, and movement, etc. Although many aspects of operational camouflage are beyond the equipment developer's control, he should be cognizant of what it can provide for the item/system and what can be done to enhance operational camouflage through development of standard operating procedures for the item/system.

### 5.1.4.3 Field Applied Camouflage.

Camouflage applied by troops in the field to themselves and their equipment continues to be an important type of camouflage. This is an opportunity to optimize local blending of color and materials and to complement the local tactical situation. Examples of this type of camouflage include the soldier who blackens his gunsight, paints his face, or garnishes his helmet with twigs and leaves. Brush might be used to cover spoor, or camouflage screens or disrupters could be placed over equipment. Here again, this aspect of camouflage is beyond the individual equipment developer's realm of control, but his actions can influence the degree of usage for field applied camouflage and thus deserves consideration.

Way the equipment developer can influence field applied camouflage include such matters as providing storage space, hooks, or support points for camouflage screens or disrupters, eliminating exposed hot surfaces which would not stay painted, and making provisions for smoke canisters (and possible firing circuits).

## 5.2 CAMOUFLAGE AS A COUNTERMEASURE

### 5.2.1 Definitions.

Countermeasures are generally interpreted to mean employment of devices and/or techniques with the objective of impairment of the operational effectiveness of enemy activity. Countermeasures are applicable to items/systems which may be thought of as either offensive or defensive in terms of primary mission (Reference 5).

Qualifying adjectives are often used in describing countermeasures (e.g., active, passive, electronic, etc.) to improve clarification. Agreement is sometimes lacking as to whether a particular countermeasure is active or passive. Smoke is a good example since it is often classified as active and/or passive depending upon the user's viewpoint. Therefore, the terms "active" and "passive" countermeasures must be used prudently.

Figure 5-3 depicts the field of countermeasures in relation to camouflage actions against RSTA detection, recognition, identification, and location. The groupings shown in Figure 5-3 separate countermeasures which are intended to prevent observation from those intended to affect observation (Reference 1).

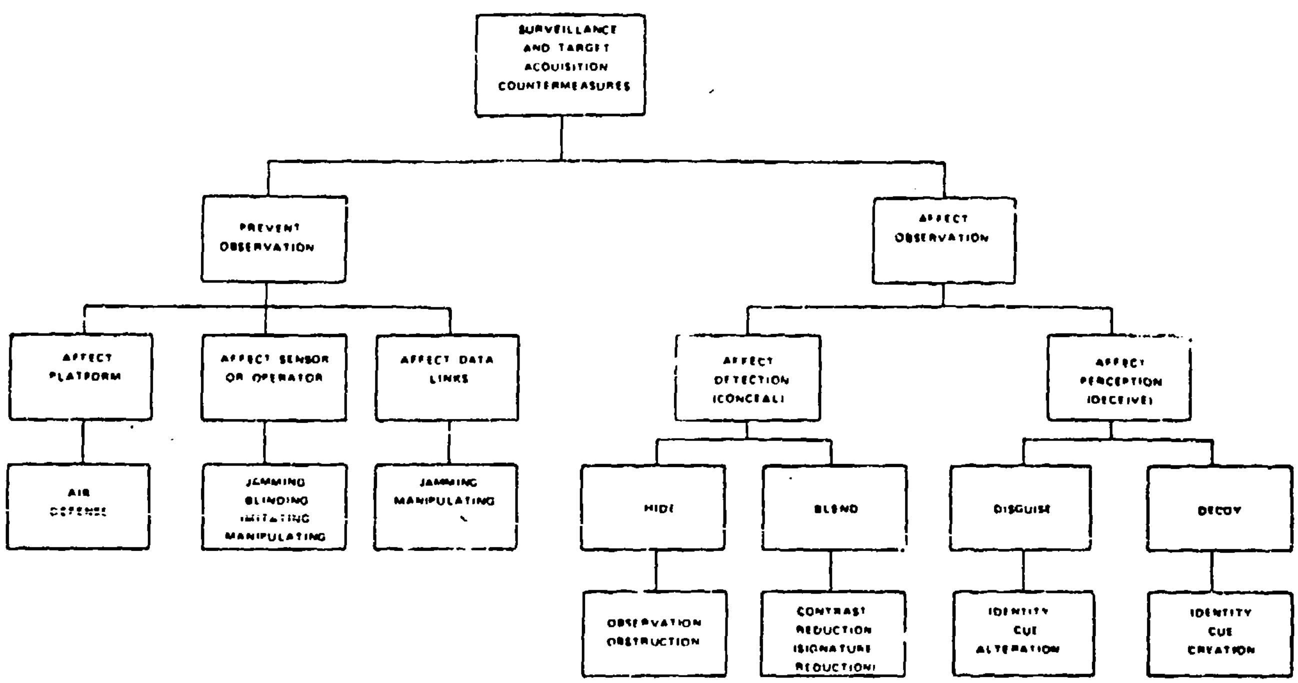


Figure 5-3. Countermeasures Related to Target Detection, Recognition, Identification, and Location.

5.2.2 Countermeasure Interfaces.

The interfaces between camouflage and other possible countermeasures are often defined by authority for some practical reason, e.g., allocating responsibility for development, deployment, etc. Definitions that are based purely on technical grounds may appear inconsistent in these situations. Figure 5-4 illustrates countermeasure fields having some contiguous boundaries with camouflage (Reference 1).

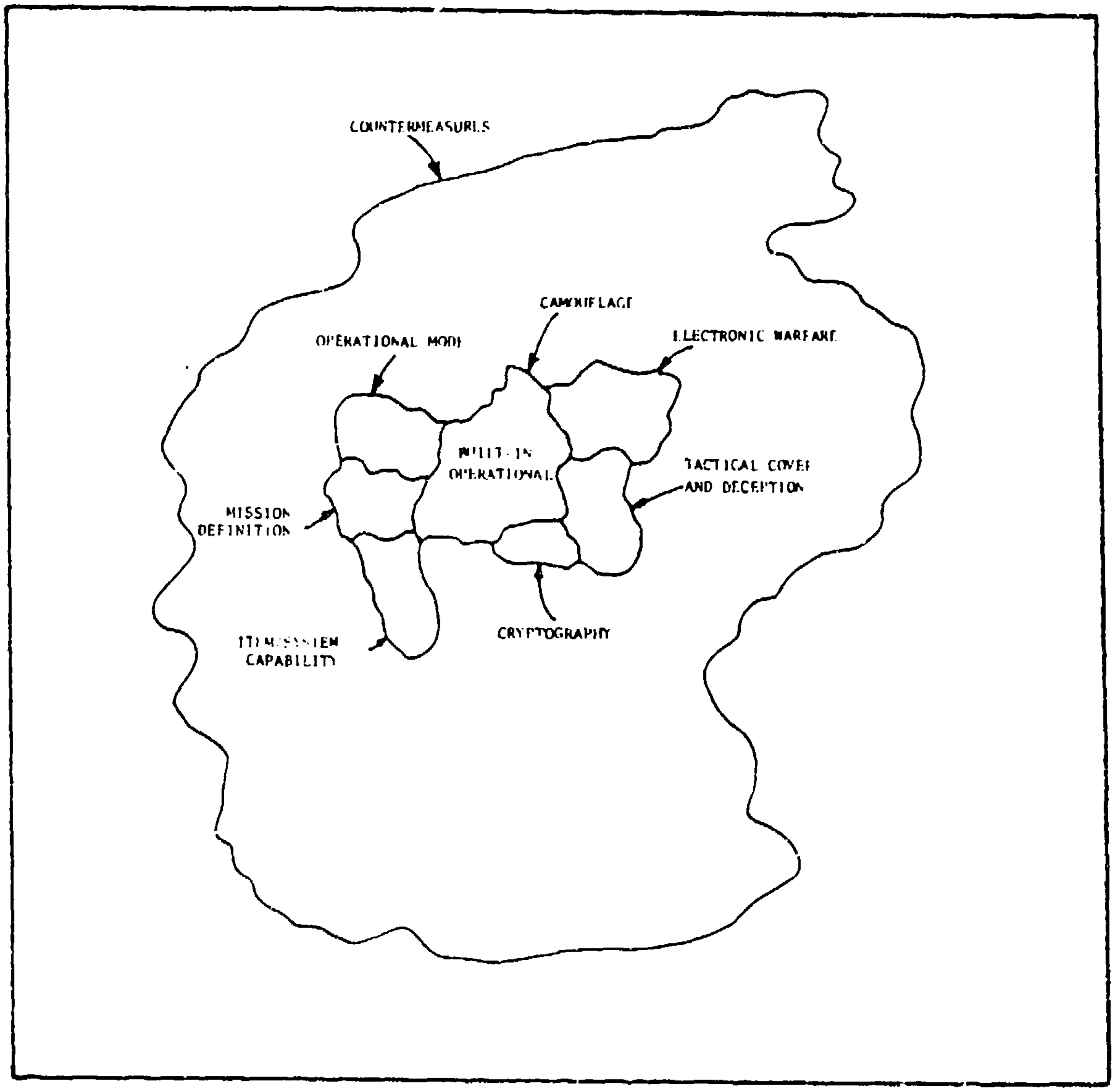


Figure 5-4. Countermeasure/Camouflage Interfaces.

5.2.2.1 Interfaces With Deception.

The terms "deception," or "cover and deception" have a definite meaning in U.S. military parlance. The latter term is an element of operations generated as part of operational planning and put into effect through annexes to field orders. Deception is offensive in concept and, while thought of in terms of protecting friendly operations, it is generally considered in a weapons or force sense (Reference 9). Cover and deception is aimed at convincing an enemy command that some capability or intent is truth when, in fact, some other capability or intent is truth -- in an operational sense. For example, the intent may be to convince the enemy that action, the preparation for which is not deniable, will take place on the 2lst, when in fact, it will take place on the l5th.

Cover and deception is a command tool and succeeds only if the enemy does what the friendly commander intended him to do. Electronic warfare, decoys, etc., may or may not be utilized in creating tactical deception. In many cases, the same physical simulation hardware may be fielded as a camouflage method for a weapons system, and also on occasion serve in a tactical deception role. For example, a camouflage screen poorly emplaced may serve as a decoy.

Camouflage is basically passive in concept and its generally accepted meaning is "to conceal or deny truth." The use of the camouflage terms disguise and decoy is also protective in concept and intended to reduce detectability and hitability through confusion of numbers, locations, and the ability to attract fire -- especially if some degree of concealment can be achieved for the real item at the same time (Reference 9). For example, if a weapon necessarily emits a signal which can be used as a locator through triangulation or other techniques (direction finding, flash and sound ranging), or as a signal for homing missiles, then decoy emitters, emplaced and operated in conjunction with the real weapon in a manner that confuses such triangulation and homing capability, constitute a protective camouflage measure which is similar to camouflage screens or pattern painting.

Employment of decoy signals and/or equipment is generally the responsibility of the unit using the archetype material. Decoys used in a camouflage sense may be signals, physical surface replicas, electromagnetic emitters, noise makers, other signature cue emitters. In fact, decoys may take many forms of simulation. If the decoys are used to protect material of similar kind and are intended for employment by units employing the archetype equipment, they are a camouflage method and bear only an indirect relationship to cover and deception.

### 5.2.2.2 Electronic Warfare (EW) Interfaces.

Electronic warfare has existed since before World Ware 11 and has been primarily concerned with radio and anti-radar measures. Like camouflage, includes denial, disguise and deception. Unlike camouflage, however, electronic warfare has productive intercept and surveillance roles (Reference 1).

The concurrent areas of EW are shown in Figure 5-5. EW is defined as "the military use of electronics involving actions taken to prevent or reduce an enemy 's effective use of radiated electromagnetic energy." It is called electronic because it initially involved the use of electronic equipment in the search, interception, location, identification, and analysis of hostile emitters, from extra low frequencies (ELF) through the ultraviolet receiving and processing systems. EW also makes use of flares, chaff, and retroreflectors.

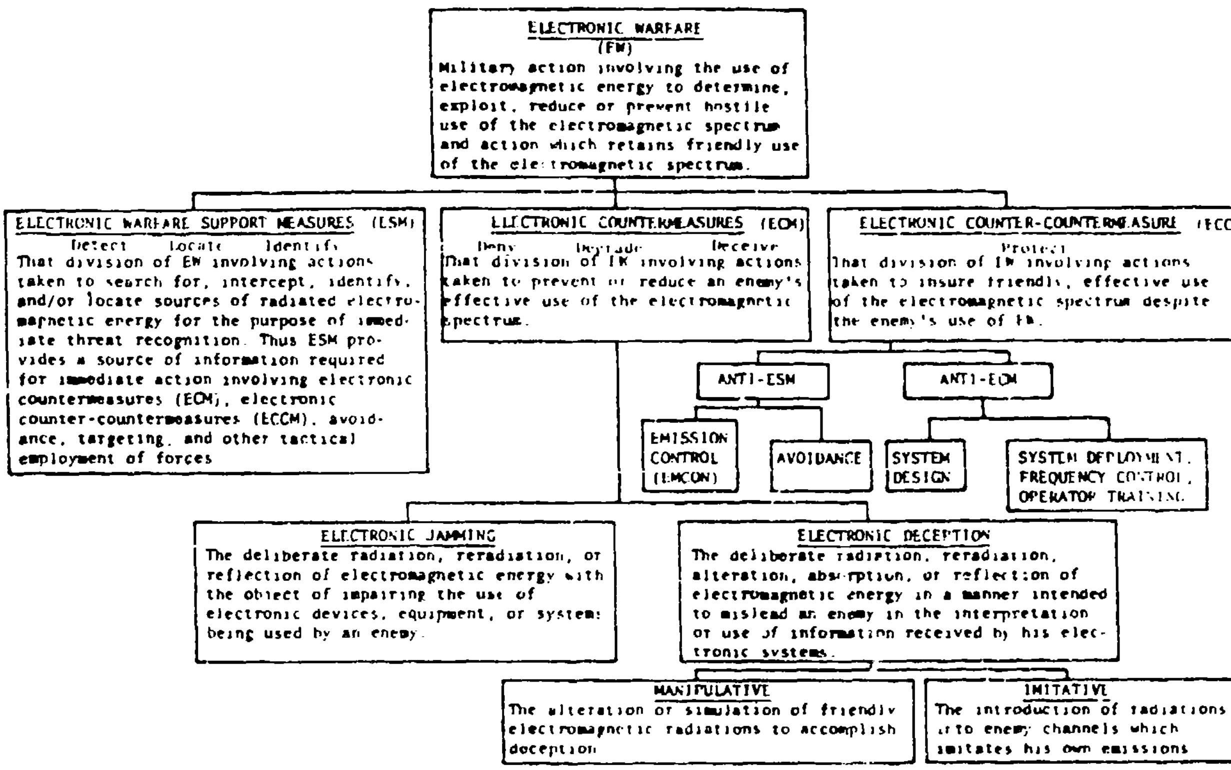


Figure 5-5. Electronic Warfare.

The field of EW includes an area identified as electronic counter-countermeasures (ECCM) to achieve anti-jamming capability in U.S. systems. In this latter role, EM is concerned with determining the vulnerability/susceptibility of U.S. and foreign electronic and weapon/missile systems to hostile EW/SIGINT techniques.

Electronic warfare is not specifically treated in this Guide, although some camouflage materials; (RAM), radar scattering screens, and certain forms shielding; might also be employed as electronic counter-countermeasures (ECCM). One area of electronic warfare within the purview of camouflage, is the creation of necessary electromagnetic emissions that provide decoys with realistic signatures. For example, a continuous wave radar decoy used in a Hawk battery camouflage design that never emits a radar signal will not provide effective deception. Providing the required radar signal is a necessary camouflage technique. Providing the radar transmitter is a function of ECCM.

5.2.3 Perception.

The output of many sensor systems, specifically imaging devices, is a scene (image) presented to a human to obtain information. The image parameters used to describe the human's ability to detect objects in the scene include object size and contrast with the background, the brightness of the scene and the image noise. These parameters are generally agreed to correlate strongly with visual performance. Large objects are easier to see than small ones. High contrast objects are easier to see than low-contrast objects. Brighter images are easier to see than low-contrast objects. Brighter images improve detection. Noisy images are less useful than noise-free images. Imposing a sensor between the human eye/brain and the object scene in the visual process offers advantages in controlling to some degree the perceived object size, the field-of-view, the contrast, brightness and noise in the human observers' scene display. The sensors (and processors) can raise the displayed image qualities above the human thresholds in the perception process and thus enhance the performance in detection/recognition/identification (Reference 7).

However, considering the human observer and the sensor system together (i.e. man-machine capability), what the equipment can do and what the observer's needs are present two separate and conflicting sets of factors. Ignoring for the moment the host of other factors affecting perception in a given situation (such as cueing, clutter, observer preparation, environment, observer task loading etc.) we note that the contrast that sensors normally yield declines rather rapidly as the size of the object in the scene gets smaller. Unfortunately, the human observer needs higher and higher contrast as the object size grows smaller and smaller in order that the eye may detect/recognize it. That we need higher contrast for smaller objects to perceive them is another way of saying contrast must increase as target spatial frequency increases, but most visual sensor outputs offer just the opposite.

In addition, the perceptibility of the target object in the scene depends upon other factors such as display size, shape/shadow (differentiation of form), color/hue/texture, reflectance (illumination response), emittance, other disassociated cues (deployment, orientation, effluent, dust/tracks etc.) and most important, what the observer expects to see as he views the scene. The psychological image "quality" in relation to what the training/preparation of the observer has conditioned him to see as a result of briefing/indoctrination is possibly the most important factor in scene interpretation and human perception performance. Expectation, conditioning, experience and task assignment are important in the psychological motivational sense and in determining the probability of success in perceiving target objects for RSTA.

## 5.3 CAMOUFLAGE METHODS AND TECHNIQUES

### 5.3.1 Categories.

Applications of camouflage involve the use of specific methods and techniques. Methods refer to the four classic categories of camouflage (hide, blend, disguise, and decoy) whereas techniques refer to detailed procedures employed to achieve these methods. Camouflage proposed for a given item/system will usually be a combination of these four methods rather than any single one. For example, the employment of a camouflage screen to conceal a truck in a natural background involves hiding the truck beneath the screen through shadow casting. The screen is designed to blend with the characteristics of foliated areas by its color, texture, and pattern design in order to appear as a continuation of the terrain. Categorization of method into four broad areas (hide, blend, disguise, and decoy) helps decide what form the camouflage solution to a particular problem should take. If, for example, the camouflage method selected for a gun emplacement is hide, it would follow that the installation of an opaque screen over the emplacement is one technique by which the method can be achieved. Figure 5-6 provides a generalized listing of techniques applicable to the four categories of camouflage methods (Reference 1).

5.3.1.1 Hide. Hide is the camouflage method by which an activity, signal, or emission is denied to a sensor through shielding, blackout or other techniques utilizing knowledge of the incapabilities of the sensor.

5.3.1.2 Blend. Blend is the camouflage method which reduces the contrast between an item/ system and the background against which it is observed. This method is generally related to surface treatments and the control of emissions/reflectivity by selection of texture, pattern arrangements, etc.

CAMOUFLAGE

| Classic Methods | HIDE | BLEND | DISGUISE | DECOY |
|---|---|---|---|---|
| | SIGNAL REDUCTION | CONTRAST REDUCTION | SUBSTITUTION OF IDENTITY CUES | CREATION OF FALSE IDENTITY |
| | 1 · Opaque Shield | 1 · Tone Down (Up) | 1 · Elimination and Obscuration of Identity Cues | 1 · Creation of False Signals |
| | 2 · Smoke | 2 · Control of Color and Texture Patterns | 2 · Incorporation of Background Cues | 2 · Creation of False Part, Item, System or Activity that Duplicates Major Detectable Identity Cues of an Archetype** |
| | 3 · Shadow | 3 · Shadow Elimination and Obscuration | 3 · Incorporation of Second Item Cues | 3 · Creation of Item Cues not Related to an Archetype |
| | 4 · Blackout | 4 · Insulation | 4 · Modification of Spoor and Activity Cues | |
| | | 5 · Emissivity Control | | |
| | | 6 · Radar Cross-Section Reduction by Geometric Shaping | | |
| | | 7 · Decoupling from Transfer Medium | | |
| | | 8 · Creation of a False Background | | |
| | | 9 · Energy Conversion | | |
| | | 10 · Use of Mirrors | | |

Figure 5-6. Camouflage Methods and Techniques.

5.3.1.3 Disguise. Disguise is the camouflage method that denies the validity of recognition by presenting a false appearance and thus denies the truth. The suppression and obscuration of existing identity features and the substitution of others intended to cause a false identification is involved. This method usually takes one of two forms: either an attempt to give the item the appearance of the backgrounds in which it will operate, or that of an object of reduced or no military consequence.

5.3.1.4 Decoy. Decoying is the camouflage method that denies the validity of a situation as opposed to an item. It is differentiated from disguise by the creation of separate signals, items or spoor representing some archetype and is not simply the alteration of identity cues as in disguise. In camouflage, decoys are used to suppress truth about a situation or installation for protective purposes, to divide fire and to attract attention away from vital components.

5.3.2 Applications. Applications of representative techniques comprising camouflage methods of hiding, blending, disguising and decoying involve the selection of physical materials and specific procedures suitable for the particular items/systems being camouflaged. Illustrations of various techniques in Tables 5-1 through 5-4 can provide guidance in choosing one or more techniques for application to particular items/systems being considered. The technique mix selected constitutes a camouflage posture (Reference 3).

Table 5-1. Hide Techniques.

TECHNIQUE 1:

Use of opaque shields (natural or artificial) between target (or item/system) and sensor which prevent transfer of energy from reaching the sensor.

EXAMPLES: Stand-off shields (insulated or otherwise treated) to permit convective cooling of a hot surface, and prevent transfer of energy from target to sensor.

Choosing a position which is not in view of potential sensors. Putting the item/system in defilade, in a barn, in an underground shelter, etc.

Bridges built under water in muddy streams.

NOTE: Additional information on hiding techniques is available in the 1000 series Data Sheets.

TECHNIQUE 2: SMOKE

A suspension in the transfer medium (air-water) that produces an opaque shield by absorbing and scattering the energy that is between a target and sensor.

EXAMPLES: A smoke screen deployed by artillery or aircraft to deny observation of some activity (e.g., a river crossing).

Smoke created around a target by generators on the target when a sensor detects the presence of hostile, illuminating energy.

Transparent smoke (aerosol) which absorbs and scatters in the IR region.

Creation of an instant opaque smoke wall by rocket or high pressure jets to deny visual acquisition of area targets as a final defense.

Use of highly absorbing gases around a radiating part. Due to dispersion, this is practical only where there is a means of containing the gas available or where the gas is required for only a limited time.

TECHNIQUE 3: UTILIZATION OF SHADOW

Positioning the target within a shadow such that the illumination level of the target is not within the recording capability of sensors using exposure times suitable for recording the general scene.

EXAMPLES: Using the shadow of a building to hide a vehicle or weapon.

TECHNIQUE 4: BLACKOUT

The cessation of activity and emissions detectable to an enemy. (applicable to intermittent and predictable observation.)

EXAMPLES: Shielding or disabling equipment that emits characteristic radiation, during the time a hostile satellite sensor is know to be in viewing position.

## Table 5-2. Blend Techniques.

TECHNIQUE 1: TONE DOWN (UP)

This is the basic concept of contrast reduction wherein the signal strength or object reflectivity is decreased or increased to approximate the background.

EXAMPLES: Application of dark colorants to a building located in a forested area to minimize contrast with the dark foliage.

Use of RAM (Radar Absorbing Materials) to reduce radar cross section.

Mixing of cool air into engine exhaust.

Use of mufflers to absorb noises.

Chemical or other means of suppression of muzzle flash.

Smoke suppression (oxygen balancing).

Application of colorants to packaging materials, cans, clothing, etc., for use in combat area to eliminate high visual contrast. This is especially helpful for kitchens and other personnel activities.

Minimizing friction between moving parts to reduce heating.

Use of photochemical colorants and surface textures to modify the luminance of the target and its inherent shadow.

Use of texturing to reduce surface tonal variations.

TECHNIQUE 2: CONTROL OF COLOR AND TEXTURE PATTERNS

The creation of patterned areas of color and texture on an object to reduce its contrast with the background. This is a principle form of camouflage employed by many forms of life. It is often combined with shadow control. In many cases, the pattern contrasts are high to further obscure the effects of shadow. There is a high correlation between the pattern and its immediate background which results in high detectability when the patterned object is moved to another background.

EXAMPLES: The use of camouflage colorants to provide the spectral characteristics found in the backgrounds of military operations. This prevents spectrational detection by remote sensors.

The application of textured leaf-like patterns over a shiny fabric for jungle combat uniforms. The depth effect is exaggerated and the camouflage effect is increased. Shine is a minor factor because the patterns break up any large areas of shine.

To be most effective, patterns must duplicate the general shadow, highlight shapes and sizes in the background. By careful choice of color and texture, small patterns which are effective at close range will blend into larger patterns as the viewing range increases.

Patterns for mobile equipment must not be applied to wheels and other moving parts if a noticeable blinking effect is to avoided. the luminance of patterns should generally not exceed the average background luminance.

Table 5-2. Blend Techniques (Continued).

The use of naturally-occurring local materials to permit blending with a greater number of backgrounds and seasonal changes.

Photochromic color coatings, which become transparent at night to reveal a second layer of camouflage and which darken in sunlight to form daytime camouflage, have been attempted but had a very short field life.

TECHNIQUE 3: SHADOW ELIMINATION AND OBSCURATION

Items are detected (ie., separated from their backgrounds) because of contrasts caused by structural outlines and shadows. Generally, under sunny conditions, inherent shadow will overpower any pattern applied, thus revealing the item.

EXAMPLES: Utilizing local brush or other material to fill in shadow and to disfigure the item's outline. Choosing positions which cause the shadows to fall on brush, or other shadow disfiguring material, or positioning on the shadow side of large foliage so the foliage shadow disfigures the item's shadow.

The use of artificial irregular attachments which will obscure inherent shadows of details and disfigure shadows cast on surrounding terrain (disrupters).

The use of reflected light from the sky to eliminate shadow. The item so treated must have a reflectance near that of the background or this technique will increase the target perceptibility.

The use of artificial light to eliminate shadow, thereby increasing the surface luminance to eliminate apparent form. These techniques have been used: (a) lamps have been placed within the shadow area, spaced close enough together to blend within the resolution capability of the sensor and controlled by a sensor viewing the background luminance; (b) searchlights, shielded from view, which are directed into the shadow of the item to be concealed; and (c) electroluminescent panels applied directly to the surface in shadow are useful only in low luminance levels.

The use of photochromic colorants which bleach in shadow and darken in sunlight (field modifiable colorants have long been sought but no practical material has yet been produced) and photochromics which become transparent in sunlight to reveal an underlying camouflage.

TECHNIQUE 4: INSULATION

Insulation reduces the rate at which heat energy is acquired or dissipated, thereby preventing rapid variations in temperature (i.e.. insulation smoothes out the time-temperature relationship). Since many backgrounds against which items will be viewed tend to have long time cycles for thermal change, insulation will assist in preventing high contrasts.

EXAMPLES: Insulation between hot parts (engine) and hoods or other enclosures is useful where the heat source exists for only short periods of time. Applied to the inner side of the enclosures, insulation increases the time required for heating the enclosures.

Insulating coatings applied to an item's surface reduce the rate of solar energy absorption.

## Table 5-2. Blend Techniques (Continued).

TECHNIQUE 5: EMISSIVITY CONTROL

Emissivity control can be obtained by the use of coatings which radiate in spectral regions not subject to detection and by physical alternation of surfaces to redistribute emissions in preferred directions. The intensity of radiation in the thermal regions of the spectrum is a function of the surface temperature and the emissivity of the surface. It is possible to alter the spectral distribution from a surface and thereby reduce the item's IR signature by utilizing coatings which have low emissivity in the spectral window regions of 3-5 microns and 8-14 microns, but high emissivity in other areas. (This capability is limited and costly.)

EXAMPLES: Control of IR emissions can be exercised by enlarging the surface and randomly configuring it to modify its directional radiating properties.

The use of thermal pillows which are flat on the inner side and pillowed to have an external area several times the inner and wrinkled to dissipate the radiation throughout more of the hemisphere above the surface.

The use of faceted IR transparent sheeting material of a suitable refractive index in the IR region, standing away form an item or surface, and designed to cause the radiation from the item's surface to be refracted in directions outside the field of view of a sensor.

TECHNIQUE 6: RADAR CROSS SECTION REDUCTION BY GEOMETRIC SHAPING

The use of shields to cover cavities and the use of designs which eliminate 90 angles of the item's structure.

EXAMPLES: Use of metal screen or camouflage screening garnish to cover cavities.

Avoid cavities in design where possible.

Use flat plate design where possible and join in angles greater than 90 if possible. For existing 90 angles, either cover with metal screen or fill with radar scattering camouflage cloth.

TECHNIQUE 7: DECOUPLING FROM TRANSFER MEDIUM

The isolation of a signal generator from energy transfer medium such as the air, water or earth, and from the item of which it is a part, to prevent the energy produced from entering the transfer medium and becoming available to the sensor.

EXAMPLES: Isolation of an outboard motor from the boat to prevent the motor vibrations from reaching the large radiating surfaces of the boat.

Isolation of a heat source by surrounding it with a vacuum will eliminate convective heat transfer.

TECHNIQUE 8: ENERGY CONVERSION

The absorption of incoming or internally generated energy and the conversion of that energy to a form which can be shielded, used or converted to a type not subject to detection.

EXAMPLES: Radar absorbing material (RAM) which converts the incoming microwave energy into heat.

Sound deadening material which converts acoustic energy to heat.

The use of coolants to absorb and dissipate energy.

Table 5-2. Blend Techniques (Continued).

TECHNIQUE 9: USE OF MIRRORS

Shaped and mirrored surfaces are used to prevent signal transfer to sensors. Mirrors can be made to blend with terrain by reflecting images of terrain, while items are hidden behind the mirrors.

EXAMPLES: A plastic sheet with a mirrored surface deployed in front of a vehicle (or other object), almost normal to the direction of observation but tilted slightly forward, will reflect the terrain directly in front of the position back to the observer while hiding the vehicle. This is effective in trees where vertical lines of the trees tend to conceal the straight edges of the mirror.

The angling of surfaces, subject to known sources of radiation used to illuminate the object for remote sensing, such that the illuminating energy is mirrored toward directions other than back to the sensors employed.

TECHNIQUE 10: CREATION OF A FALSE BACKGROUND

In instances where cover or a confusing background is lacking, a confusing background may be created.

EXAMPLES: In a dry prairie where there are few trees or other features to assist in concealment, the tactic of burning grass in patches large enough to accommodate vehicles have been employed with good results.

## Table 5-3. Decoy Techniques.

TECHNIQUE 1: CREATION OF FALSE SIGNALS

Some items of military equipment give off characteristic signals of an acoustic, seismic, or electromagnetic nature. Reconnaissance operations by unfriendly forces can utilize these signals to locate and identify friendly materiel. Creation of false signals, which the enemy accepts as valid, serve to draw attention from actual materiel, cause the enemy to consume additional energy or firepower, draw false conclusions about friendly force position or strength, and otherwise confuse or disrupt the enemy's operations.

EXAMPLES: Certain missile launchers employ active radars whose signals can be duplicated by a decoy transmitter. Enemy systems designed to detect or home-in on this signal will therefore be deceived. Some items of military equipment are vulnerable to attack by weapons employing thermal-infrared-seeking devices. Deployment of decoy thermal infrared sources will give false detection information to the enemy and will serve to distract or redirect the thermal-infrared-seeking devices.

TECHNIQUE 2: CREATION OF FALSE PART, ITEM, SYSTEM OR ACTIVITY THAT DUPLICATES MAJOR DETECTABLE IDENTITY CUES OF AN ARCHETYPE

Decoy objects are used to draw attention or enemy fire, thereby diluting the enemy's efforts to detect and destroy real items of equipment. The sophistication (degree of fidelity) required of decoys increases as a sensor sophistication increases; future decoys will require simulation of archetype signatures in the thermal infrared and radar spectral region, as well as in the visual region.

EXAMPLES: A tank decoy can be equipped with recordings of the actual sounds of a mobile tank and its weapon reports, as well as radar reflective materials and thermal sources that simulate a real tank.

The Hawk missile launcher decoy simulates the geometry and visual appearance of a real launcher. Radar reflective materials are also incorporated that simulate the radar cross section of a real launcher, and a radar transmitter can be used which will simulate the battery's active radar system.

TECHNIQUE 3: CREATION OF ITEM CUES NOT RELATED TO AN ARCHETYPE

This decoy technique involves creating a cue (signal, emission, etc.) that is recognized as not naturally occurring and is therefore considered a possible threat.

EXAMPLES: A camouflage screen, erected but covering no item of military value, will draw attention or firepower, or both, if placed so it can be discovered by the enemy. Saturating an area with "empty" screens can significantly confuse or distract the observers. Other examples of this decoy technique are: mirrors or flashlights used to direct light toward enemy observers; a corner reflector or broad-band radar transmitter hidden among natural surroundings; acoustic recordings of mobile equipment passing through a forest; a seismic wave generator hidden behind natural obstructions.

## Table 5-4. Disguise Techniques.

TECHNIQUE 1: ELIMINATION AND OBSCURATION OF IDENTITY CUES

The methods of hiding and blending are of limited usefulness to the camouflage of military materiel where it is necessary to defeat observation at close range. The perceptibility of an item/system is related to the real or imagined threat it poses to an observer. The elimination of characteristics in materiel and postures indicating threats to an enemy tend to lessen perceptibility (i.e., a weapon is feared but a truck is not). Removing or covering the characteristics which indicate that an item is still a weapon will make it appear to pose little threat.

Disguise can prevent the tracking of force structure without denying the force's presence. Disguise is used in conjunction with other operational techniques such as moving a force system by infiltration in lieu of convoy or by mixing several units at random in convoy.

EXAMPLES: Tarpaulins placed over an item to which air bags, boxes, or other form altering means have been attached conceals the recognition cues which are associated with threats. Obscuration of the gun barrels of artillery or tanks, by use of camouflage materiel (nets, disrupters, etc.) will prevent or delay recognition of the weapon.

TECHNIQUE 2: INCORPORATION OF BACKGROUND CUES

This technique is related to the hiding and blending methods discussed previously; it differs because the act is to add items from the natural environment, thereby giving to the item/system cues which are characteristic of the innocuous background.

EXAMPLES: Adding branches of foliage to a weapon can make it appear as a natural growth of brush.

Strategic placement of large rocks on, or boulders around the military item will effect a level of disguise in a rocky environment.

TECHNIQUE 3: INCORPORATION OF SECOND ITEM CUES

This technique involves changing the appearance of a military item to that of another man-made item. The appearance change is to that of a less threatening or less valuable item.

EXAMPLES: An item/system can be downgraded in appearance by incorporating cues of another military item/system. The term appearance is used here to describe cues recognizable by any of the human senses or inanimate sensor devices (e.g., the sound emitted by a mobile weapon can be damped or otherwise altered to duplicate the sound of a less threatening vehicle). Also, the radar cross section of a large, valuable item/system can be reduced (by selective placement of radar absorbing materials) to yield the cross section of a smaller, less valuable item/ system.

An example of visual appearance downgrading is the alternation of a military vehicle to give it cues of a civilian vehicle. This technique could have particular application in an urban environment.

Table 5-4. Disguise Techniques (Continued).

| |
|---|
| TECHNIQUE 4: MODIFICATION OF SPOOR AND ACTIVITY CUES<br><br>Mobility equipment items frequently leave a trail of environmental changes, or deployment of certain kinds of equipment frequently presents a characteristic pattern. These resultant spoor and activity cues can be modified to deter identification of the specific equipments or activities.<br><br>EXAMPLES: Deployment of certain weapons has historically taken a specific geometric form (e.g., tanks in a circle or artillery in a semicircle). Substituting an irregular geometry for these cues can delay the enemy's detection or identification of the weapons.<br><br>Trails left by tracked vehicles are distinguishable from those of wheeled vehicles. Modification of the trails by dragging devices, etc., can delay recognition of a tracked vehicle trail.<br><br>A missile system, having fixed physical characteristics which require that each element of the firing battery be interconnected with cable of fixed length and have a clear path between elements for line-of-sight communications, exhibits a fixed ground pattern of deployment. This is usually reinforced by standard operating procedures which give quick reaction capabilities. These ground patterns are quickly learned by an enemy and greatly aid in recognition. A variable ground pattern of deployment will prevent this recognition.<br><br>Characteristic warm-up procedures or pre-firing activities can be modified to prevent recognition. |

5.3.3 Characteristic Signatures of Equipment.

A variety of camouflage problems may exist for an item of equipment or system for each significant event or mode of operation of the equipment on the battlefield. Tables 5-5 through 5-13 give descriptions of characteristic signatures and sources (Reference 1). The spectral regions of RSTA systems capable of detecting and recording these signatures are indicated along with possible camouflage techniques to reduce these same signatures. Signature importance is not evaluated in these tables since that question is answered on an individual basis by the threat assessment in Section 3.

These tables serve two purposes. They aid the developer in considering all aspects of the perceptibility of his equipment to the enemy. They also serve as an index to specific camouflage data sheets by indicating the spectral regions of concern for each signature. The following key is used in the tables to signify the individual spectral regions. A discussion of the RSTA systems operating in each of these regions is found elsewhere.

| | | | |
|---|---|---|---|
| UV | Ultraviolet | EMP | Electromagnetic Pulse |
| V | Visual | M | Magnetic |
| NIR | Near Infrared | A | Acoustic, Sonic |
| TIR | Thermal Infrared | S | Seismic |
| R | Radar | C | Chemical |
| RF | Radio Frequency | O | Other |

Table 5-5. Characteristic Signatures of Weapons.

| SYSTEM MODE OR EVENT | SIGNATURE SOURCE | SIGNATURE DESCRIPTION | SPECTRAL REGION | CAMOUFLAGE |
|---|---|---|---|---|
| Projectile Launch, Rocket Launch | Muzzle Blast, Rocket Exhaust | Sound pulse | A | Silencer |
| | | Propellant gas cloud | V, IR, C | Smoke, propellant chemistry change |
| | | Dust cloud | V, TIR | Site preparation, smoke |
| | Muzzle Flash, Rocket Exhaust | Line-of-sight flash and atmospheric scattered flash, EMP | V, NIR, TIR, R, EMP | Flash hider, propellant chemistry change, daylight operation, decoy blast, decoy flash |
| | Weapon Recoil | Ground shock | S | |
| Projectile Flight | Projectile | Visible object | V | Low visibility coating |
| | | Radar cross section | R | RAM, low RCS geometry |
| | | Hot object | TIR | Low emissivity coating |
| | Supersonic Projectile | Flow noise | A | |
| | Projectile Impact | Flash, shock, blast | V, NIR, TIR, R | |
| Tactical Deployment | Tactical Configuration | Characteristic shape, size, appearance and location | V, NIR, TIR, R | Natural concealment, low gloss coating, pattern painting, screen smoke, chaff, disrupters |
| | Ground Pattern | Characteristic relationship with other objects | V, NIR, TIR, R | Variable employment doctrine, decoy |
| | | Presence of engine generators | V, NIR, TIR, RF | (see Table 5-8 for engine generators) |
| | | Presence of communication equipment | V, NIR, TIR, RF | (see Table 5-8 for communications equipment) |
| | | Disturbed soil | V | Soil colorant, tone down materials |
| | Activity | Characteristic type, sequence, and relationship to other events | V, NIR, TIR | Avoid standardized activities |
| | | Muzzle blast ground pattern | V | Site preparation |
| | | Hot barrel and other equipment parts | TIR | IR shields, insulation, cooling, low emissivity coatings, reposition hot spots |
| | | Power supply, noise, heat | A, TIR | Mufflers, frequency modification, IR shield, insulation, cooling, low emissivity coatings, reposition hot spot |
| | | Effluents | V, TIR, C | Cool exhaust, redirected exhaust, low visibility, exhaust, smoke |

Table 5-5. Characteristic Signatures of Weapons (Continued).

| SYSTEM MODE OR EVENT | SIGNATURE SOURCE | SIGNATURE DESCRIPTION | SPECTRAL REGION | CAMOUFLAGE |
|---|---|---|---|---|
| Tactical Deployment | Activity | RF emission | RF | ECCM |
| | | Litter | V | Discipline, tone down packing materials |
| | Insulation Dependent Temp. Changes | Thermal contrast between equipment and background | TIR | |
| Road March | Mobile Configuration | Characteristic shape, size and appearance | V, NIR, TIR | Low gloss coating, pattern painting, covered in transit, disguise kit, disrupters |
| | March Order | Characteristic convoy arrangement | V, NIR, TIR | Avoid standardized configuration, ubiquitous vehicles |
| | Route | Route options restrained by terrain trafficability | V, NIR, TIR, R | Increase weapon mobility |
| | | Tire, track marks on ground | V | Discipline, soil colorants |
| | Motion | Dust cloud | V, TIR | Dust control device |
| | | Ground impact | S | Seismic wave generator, quiet tracks |
| | | Equipment noise | A | Secure equipment, sound control, frequency modification |
| | | Movement | V, TIR, R | Smoke, chaff, natural terrain masking |
| | | Direction | V, TIR, R | Smoke, chaff, natural terrain masking |
| | | Large metal mass | M | |
| Rear Area Storage | Storage Configuration | Characteristic shape, size, appearance, location and relationship with other objects | V, TIR, R | Covered storage, natural concealment, disguise kit, low gloss coating, pattern painting, RAM, low RCS geometry |
| Resupply | Logistic System | Fixed supply points | V, TIR | Variable resupply system, concealed supply point |
| | | Characteristic resupply vehicle | V, TIR | Non-unique vehicle, disguise kit |
| | Activity | Activity | V, TIR | Covered work area, screens |
| | | Repair tools | V, TIR | Covered work area, screens, disguise kit |
| | | Noise | A | Mufflers |

Table 5-6. Characteristic Signatures of Vehicles.

| SYSTEM MODE OR EVENT | SIGNATURE SOURCE | SIGNATURE DESCRIPTION | SPECTRAL REGION | CAMOUFLAGE |
|---|---|---|---|---|
| Moving | Mobile Configuration | Characteristic shape, size and appearance | V, NIR, TIR | Low gloss coating, pattern painting, disguise kit, disrupters |
| | March Order | Characteristic convoy arrangement | V, NIR, TIR | Avoid standardized configuration, ubiquitous vehicles |
| | Route | Route options restrained by terrain trafficability | V, NIR, TIR, R | Increase vehicle mobility |
| | | Tire, track marks on ground | V | Discipline, soil colorants |
| | Motion | Dust cloud | V, TIR | Dust control device |
| | | Ground impact | S | Seismic wave generator, quiet tracks |
| | | Equipment noise | A | Secure equipment, sound control, frequency modification |
| | | Movement | V, TIR, R | Smoke, chaff, natural terrain masking |
| | | Direction | V, TIR, R | Smoke, chaff, natural terrain masking |
| | | Large metal mass | M | |
| | | Power supply, noise | A | Mufflers, frequency modification |
| | | Power supply, heat | NIR, TIR | IR shield, insulation cooling, low emissivity coating, reposition hot spots |
| | | Power supply, effluent | V, C, NIR, TIR | Cool exhaust, redirected exhaust, low visibility exhaust, smoke |
| | | Power supply, RF emission | RF | ECCM |
| | | Hot wheels, tracks | TIR | IR shields |
| | | Hot vehicle parts | TIR | IR shields, low emissivity, coatings, insulation, cooling, reposition hot spots |
| Combat | Firing Weapons | (SEE WEAPONS, PROJECTILE LAUNCH) | | |
| | Active Target | IR searchlight | NIR | Restricted use, pulse mode |
| | Acq. Devices | Laser rangefinder | V, NIR | Restricted use, pulse mode |
| | Enemy Target Acquisition System | Laser rangefinder | V, NIR, TIR | Low emissivity, diffuse coating, mirrors, threat monitor |
| | | Laser target designator | V, NIR, TIR | Same as above |

Table 5-6.Characteristic Signatures of Vehicles (Continued).

| SYSTEM MODE OR EVENT | SIGNATURE SOURCE | SIGNATURE DESCRIPTION | SPECTRAL REGION | CAMOUFLAGE |
|---|---|---|---|---|
| Stationary | Tactical Configuration | Characteristics shape, size and appearance | V, TIR, R | Natural concealment, low gloss coating, pattern painting screens, smoke, chaff, disrupters, disguise kit decoys, RAM, low RCS geometry, shadow control, windshield glare, control |
| | Ground Pattern | Characteristic relationship with other objects | V, TIR, R | Change deployment doctrine, soil colorants, tone down materials |
| | Activity | Characteristic type sequence and relationship to other events | V | Avoid standardized activities |
| | Insulation Dependent Temp. Changes | Thermal contrast between equipment and background | TIR | |
| Resupply | Logistics System | Fixed supply points | V, TIR | Variable resupply system, concealed supply point |
| | | Characteristics supply vehicle | V, TIR | Non-unique vehicle, disguise kit |
| Maintenance | Activity | Noise | A | Mufflers |
| | | Activity | V, TIR | Covered work area, screens |
| | | Repair tools | V | Covered work area, screens, disguise kit |
| Rear Area Storage | Storage Configuration | Characteristic shape, size, appearance, location and relationship with other objects | V, TIR, R | Covered storage, natural concealment, screens, disguise kit, low gloss coatings, pattern painting, RAM, low RCS geometry |

Table 5-7Characteristic Signatures of Aircraft.

| SYSTEM MODE OR EVENT | SIGNATURE SOURCE | SIGNATURE DESCRIPTION | SPECTRAL REGION | CAMCUFLAGE |
|---|---|---|---|---|
| Tactical Flying | Flight Noise | Engine noise | A | MOE, mufflers |
| | | Blade noise | A | MOE, quiet blades |
| | Flying Configuration | Characteristic shape, size, and appearance | V, TIR, R | MOE, smoke, chaff, RAM, low RCS geometry, pattern paint, low gloss paint, low contrast with background |
| | | Sun glint | V, NIR | Low emissivity coating, canopy redesign |
| | | Engine exhaust plume | V, C, NIR, TIR | Low emission engine, fuel chemistry change |
| | | Engine RF emissions | RF | ECCM |
| | | Hot spots | TIR | IR shield, cooling, low emissivity, coating, insulation, reposition hot spots |
| Weapons Firing | (SEE WEAPONS, PROJECTILF LAUNCH) | | | |
| Parked, Downed | Ground Configuration | Characteristic shape, size, appearance and relationship with other objects | V, TIR, R | Covered storage, natural conceal-ment, screens, smoke, chaff, decoy |
| Resupply | (SEE WEAPONS, RESUPPLY) | | | |
| Maintenance | (SEE WEAPONS, MAINTENANCE) | | | |
| Rear Area Storage | (SEE WEAPONS, REAR AREA STORAGE) | | | |

Table 5-8. Characteristic Signatures of Engine Generator Sets.

| SYSTEM MODE OR EVENT | SIGNATURE SOURCE | SIGNATURE DESCRIPTION | SPECTRAL REGION | CAMOUFLAGE |
|---|---|---|---|---|
| Tactical Employment | Item Configuration | Characteristic shape, size and appearance | V, TIR | Natural concealment, low gloss coating, pattern painting, screens, disguise kit |
| | | Engine noise | A | (See Weapons-Power Supply) |
| | | Engine heat | NIR, TIR | (See Weapons-Power Supply) |
| | | Engine effluents | V, TIR, C | (See Weapons-Power Supply) |
| | | Engine RF emissions | RF | (See Weapons-Power Supply) |
| | | Generator RF emissions | RF | ECCM |
| | Insulation Dependent Temp. Changes | Thermal contrast between equipment and background | TIR | |
| Refuel | Logistics System | Characteristic refuel vehicle or procedure | V | Non-unique vehicle, disguise kit, concealed refuel procedure |
| Rear Area Storage | Item Configuration | Characteristic shape, size and appearance | V, TIR | Covered storage, natural concealment, low gloss coating, pattern painting, screens, disguise kit |
| Transport | Item Configuration | Characteristic shape, size and appearance | V, NIR, TIR, R | Low gloss coating, pattern painting, covered in transit, disguise kit, transported by ubiquitous schedule |

Table 5-9. Characteristic Signatures of Communications Equipment.

| SYSTEM MODE OR EVENT | SIGNATURE SOURCE | SIGNATURE DESCRIPTION | SPECTRAL REGION | CAMOUFLAGE |
|---|---|---|---|---|
| Tactical Employment | System Configuration | Characteristic shape, size, appearance, location and relationship with other objects | V, TIR | Natural concealment, low gloss coating, pattern painting, screens, disrupters, disguise kit, ubiquitous container |
| | | Presence of antennae | V | Lower antennae, slot antennae |
| | | Presence of engine generator | V, TIR, A | (See Engine Generator Set) |
| | Activity | Electronic emissions | RF | ECCM |
| | | Characteristic traffic | V, A | Natural concealment, discipline, concealed traffic routes |
| | | Equipment hot spots | TIR | IR shields, insulation, cooling, low emissivity coatings, reposition hot spots |
| Transport | Item Configuration | Characteristic shape, size and appearance | V, TIR, R | Low gloss coating, pattern painting, covered in transit, disguise kit, kit, transport by ubiquitous vehicle |
| Rear Area Storage | Item Configuration | Characteristic shape, size, appearance, location and relationship with other objects | V, TIR | Covered storage, natural concealment, screens, disguise kit, low gloss coating, pattern painting, ubiquitous container |

Table 5-11.Characteristic Signatures of Tactical POL Equipment.

| SYSTEM MODE OR EVENT | SIGNATURE SOURCE | SIGNATURE DESCRIPTION | SPECTRAL REGION | CAMOUFLAGE |
|---|---|---|---|---|
| Construction | Construction Activity | | V | Colorant for disturbed soil |
| Operational | Bulk Storage Container | Characteristic shape, size, appearance, location, and relationship with other | V, TIR | Concealed area, low gloss surface, pattern painting, screens, disrupters, disguise kit |
| | | Thermal lag | TIR | |
| | Pipe Lines | Characteristic shape, size, appearance, location, and relationship with other objects | V, TIR | Route under natural concealment, low gloss coating, screens, disrupters, pipeline covers |
| | | Thermal lag | TIR | |
| | Tank Trucks | Activity, presence | V, TIR | Locate terminal under natural concealment, discipline |
| | Engine, Pump, Filter | Characteristic shape, size and appearance | V, TIR | |
| | | Noise | A | (See Weapons-Power Supply) |
| | | Heat | NIR, TIR | (See Weapons-Power Supply) |
| | | Effluents | V, TIR, C | (See Weapons-Power Supply) |
| | | RF emissions | RF | (See Weapons-Power Supply) |

Table 5-12.Characteristic Signatures of Shelters, Tentage, and Containers.

| SYSTEM MODE OR EVENT | SIGNATURE SOURCE | SIGNATURE DESCRIPTION | SPECTRAL REGION | CAMOUFLAGE |
|---|---|---|---|---|
| Tactical Employment | Tactical Configuration | Characteristic shape, size, appearance, location, and relationship with other objects | V, TIR, R | Natural concealment, low gloss coating, pattern painting, screens, disrupters, disguise kit, ubiquitous design, RAM, low RCS geometry |
| | Specialized Activities Associated with the Contents | Noise source | A | (See Weapons-Power Supply) |
| | | Heat source | TIR | (See Weapons-Power Supply) |
| | | RF source | RF | ECCM |
| | | Light source | V | Discipline, shutters, filters |
| | | Litter source | V | Discipline |
| | | Characteristic traffic | V | Discipline, concealed area |
| Transport | Item Configuration and appearance | Characteristic shape, size | V, TIR, R | Low gloss coating, pattern painting, covered in transit, disguise kit, ubiquitous design |
| Rear Area Storage | Item Configuration | Characteristic shape, size and appearance | V, TIR, R | Above, plus natural concealment, covered storage, RAM, screens, low RCS geometry |

Table 5-13.Characteristic Signatures of Mines.

| SYSTEM MODE OR EVENT | SIGNATURE SOURCE | SIGNATURE DESCRIPTION | SPECTRAL REGION | CAMOUFLAGE |
|---|---|---|---|---|
| Minefield | Emplaced Configuration | Characteristic shape, size and appearance | V, TIR | Bury, hide, conceal, disguise, decoy |
| | Mine Material Different From Soil | Altered ground temperature distribution | TIR | Match characteristic |
| | | Altered ground electrical characteristic | RF | Match characteristic |
| | | Altered ground magnetic characteristic | M | Match characteristic |
| | | Altered ground mass characteristic | | |
| Transport | Packaged Configuration | Characteristic shape, size and appearance | V, TIR | Low gloss coating, covered in transit, ubiquitous container, disguise kit |
| Rear Area Storage | Packaged Configuration | Characteristic shape, size and appearance | V, TIR | Low gloss coating, covered storage, natural concealment, disguise kit, ubiquitous container |

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# CAMOUFLAGE TESTING AND EVALUATION


HOW EFFECTIVE ARE THESE INFLATABLE DECOYS?

# SECTION 6

# CAMOUFLAGE TESTING AND EVALUATION

## 6.1 GENERAL

This section addresses the unique aspects of testing and evaluation related to the application of camouflage to military materiel. While it concentrates on testing and evaluation of camouflage solutions, it also recognizes that these measures must be integrated into the overall test and evaluation process for the system under development. It is neither necessary nor desirable to perform independent testing exclusively to evaluate the effectiveness of camouflage measures applied. These procedures must be integrated into the overall testing program as one more aspect requiring evaluation in conjunction with overall system performance.

The purpose of the tests and subsequent evaluation of the test results is to demonstrate the reduction in the probability of detection/identification/location of the camouflaged item against hostile surveillance and target acquisition methods. This, in turn, increases the item's battlefield survivability by reducing the time interval available to hostile forces for locating and destroying friendly units/equipment.

While the overall responsibility for testing remains with the system developer, assistance in testing for camouflage is available and should be requested from TROSCOM's U.S. Army Belvoir Research, Development and Engineering Center (BRDEC). The degree of assistance can vary from minor consultation to full scale participation in system development tests and their evaluation. The camouflage experts at BRDEC can offer the developer major assistance in complicated technical areas of camouflage and can assure that the correct measures of performance are evaluated to determine the improved effectiveness obtained by the camouflage adopted.

## 6.2 TYPES OF CAMOUFLAGE TESTING AND EVALUATION

### 6.2.1 Background Testing.

Since detection cues consist of contrasts between perceptible qualities of the item as revealed by the sensors of interest (obtained from the threat evaluation) and the background environment in which it is operating, it is important to measure and characterize the background without the system being present.

This background must be characterized in all sensible ranges (i.e., visual, audible, IR, UV, and radar as appropriate) depending on performance to be evaluated, as outlined in the system requirements documents. Recognizing that the camouflage solutions to be tested are a compromise (intended to work in the greatest number of possible environments but not optimized to any specific one), there are variations in the possible backgrounds in which they will be employed. Therefore, it is important to measure and characterize the background in order to be able to distinguish the system's sensible signature from the background.

6.2.2 Performance Testing.

6.2.2.1 General. Camouflage goals are frequently stated in terms of the desired perceptibility performance required of a camouflaged system/item in response to a particular threat in a given environment. The expected outcome of such a situation is expressed as a measure of performance (MOP) of the camouflage treatment.

An example of perceptibility testing would be a comparison of the probability of detection of a camouflaged tank vs. a bare tank by a missile seeker as shown below in Figure 6-1.

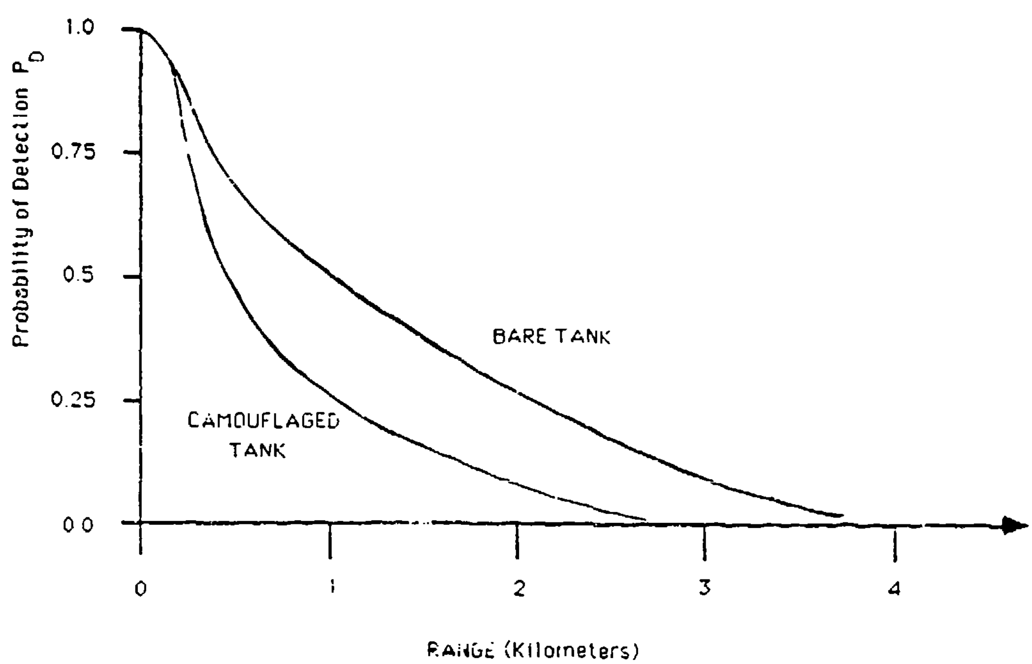


Figure 6-1. Effect of Camouflage on the Detectability of a Tank.

The difference between the two curves is an indication of the enhanced survivability of the camouflaged tank over the bare tank. The improved performance can be quantified as the reduction in the range at which detection will occur with a given frequency or probability.

The MOPs should be chosen so that the test results will be a useful input to a subsequent Military Worth Analysis. Examples of useful MOPs include: target acquisition rate, probability of detection as a function of range and search time, and location error as a function of range. Also, the factors affecting the results of a series of observations should be considered when evaluating the data. False conclusions based on unwarranted extrapolations of small sample results should be guarded against. This is especially true with respect to camouflage tests involving hiding and blending. Environmental conditions such as lighting, background and atmosphere may change during a series of trials and sometimes during one set of observations.

6.2.2.2 Types of Performance Tests. Four types of camouflage performance tests in order of increasing cost are simulation, scale modeling, analytical modeling and field trials. In order to insure validity, all entail the following steps: creation of a realistic situation, methodical conduct of the testing, measurement and recording of all critical test variables, and the statistical design and analysis of test procedure and results.

Of these tests, field trials are both the most realistic and the most expensive. The high costs of field trials result from the logistics, coordination, and replication required. Field tests are therefore often restricted to final proof tests of completed camouflage treatments, conducted in conjunction with other system performance tests.

Analytical modeling appears to offer great future potential since it enables a wide variety of designs to be evaluated rapidly. However, there are two major limitations in existing models. Since the detection and acquisition process is not well defined, they are only imperfectly modeled. Also, the analytical models tend to be aggregated in that only the gross features and characteristics of the camouflaged target are modeled and fine distinctions are difficult to handle.

Scale modeling consists of viewing miniature physical models against scaled backgrounds. This type of modeling is most useful in determining the perceptibility reductions produced by contrast reduction and configuration changes. Care must be taken to consider atmospheric and scaling effects (e.g., different materials and design may be required in the scaled down model in order to achieve the same effect produced by the full scale item). This type of modeling is not restricted to the optical region only, but can be used whenever a sensor can be modeled in scale. There are several elaborate facilities in the U.S. with terrain models suitable for camouflage testing. Some of these are listed in Appendix C. An example of scale modeling outside the visual region is the BRDEC 100-GHz Radar Cross Section Measurement and Diagnostic Imaging Facility used to scale down target dimensions for anlaysis of target returns for threat frequencies below 16 GHz. Other scale and microwave band combinations are possible.

Simulations are most useful in early screening of proposed camouflage designs where an evaluation and interpretation of what is observed is desired. For example, visual simulations produce a picture by projecting images from one or more sources or by displaying a sequence of electronically generated scan lines. Versatility is achieved in these systems by the technical ability to embed images of the camouflaged item in the background scene.

## 6.3 PLANNING FOR CAMOUFLAGE TESTING AND EVALUATION

### 6.3.1 Test and Evaluation Master Plan (TEMP).

The TEMP is an overall test and evaluation plan, prepared during the Concept Exploration Phase of the acquisition process and designed to identify and integrate objectives, responsibilities, resources, and schedules for all test and evaluation associated with a particular acquisition. It is a dynamic document which is reviewed and revised throughout the acquisition process; it is updated prior to each milestone decision. The TEMP consolidates planning for developmental and operational testing. It is a summary document and does not replace the design and detailed planning required for the execution and management of tests.

The TEMP provides reviewing authorities with high quality quantitative test and evaluation data upon which to base acquisition risk assessments. It includes a summary of testing and evaluation completed to date. Test and evaluation events and results are reported with emphasis on required performance characteristics and critical issues and on projected or demonstrated operational effectiveness and suitability. Along with the TEMP, program managers' briefings and independent test agency evaluation reports provide the data used by reviewing authorities to determine system readiness to advance further in the acquisition cycle.

The TEMP also provides reviewing authorities with an overview of future test and evaluation plans and thus with a measure of confidence in the preparation required for the system to proceed to the next step in the development sequence. The TEMP outlines projected testing and evaluation so that reviewing authorities can be assured that critical issues have been sufficiently identified, that testing to resolve them will be adequate and properly coordinated, and that the resources and facilities required to perform testing and evaluation are available.

### 6.3.2 Integration of Camouflage Goals Into System TEMP.

6.3.2.1 Critical Issues. Testing begins early in the system development cycle in order to identify risks and to estimate operational potential. Therefore, the technical and operational characteristics which are essential for system performance, effectiveness, and suitability are identified as critical issues as early as possible in the acquisition cycle. A critical issue is a problem in system development which must be resolved in order for the system to perform satisfactorily in its intended environment. It may be technical or non-technical and may relate to system effectiveness or suitability. The main purpose of test and evaluation is to ensure that the critical issues have been resolved.

6.3.2.2 Camouflage Performance Goals. The stated camouflage performance in requirements documents are integrated into the TEMP by specifying the desired results of various tests in terms of one or more measures of performance (MOPs). MOPs are quantitative descriptions of the expected outcome of an encounter between a camouflaged item/system and a specific combination of threat sensors. They, in turn, can serve as a basic input to a subsequent military worth analysis involving the survivability of a particular force type in a given scenario.

The inclusion of camouflage performance goals in the TEMP depends on the importance of the camouflage to the survivability of the sytem. If the system is judged to be Camouflage Critical (CC) or Camouflage Sensitive (CS)--see Section 2 above-- it is very likely that testing and evaluating the camouflage developed for the system will be judged a critical issue and therefore must be tested.

6.3.2.3 Specific TEMP Items. The following specific items in theTEMP should be considered for inclusion of camouflage:

- System Details: Describe the type of camouflage "measures" ("built-in" and "field applied") incorporated into Camouflage Critical and Camouflage Sensitive items/systems.

- Program Summary: Indicate how camouflage testing is integrated into the overall test plan.

- DT&E Outline: Emphasize the development tests which will provide quantitative data on camouflage performance so as to enable an early objective evaluation of camouflage effectiveness against specified threats.

- OT&E Outline: Emphasize the operational tests which will serve to evaluate the battlefield effectiveness of camouflage measures employed. Consider all applicable threats likely to be encountered in combat. Testing should be performed under realistic combat conditions. Consider the use of simulation to create the required environments and events.

- T&E Resource Summary: Consider the use of simulations, models and test beds in estimating the resources required to adequately test camouflage treatments.

6.3.3 Standards.

The measures of performance (MOP) which are ascribed to the selected camouflage goals that are incorporated in the system requirements documents become the standards to which the system must be tested for adequacy in the T&E phase of development. They are incorporated into the Required Operational Capabilities document (ROC). An adequate demonstration of their presence is a necessary condition for meeting the required performance goals.

## 6.4 METHODOLOGY FOR CAMOUFLAGE TESTING AND EVALUATION

6.4.1 Requirements to be Evaluated.

These come from the TEMP, which in turn come from the requirements documents as described above. These requirements establish the number and types of tests that must be undertaken in order to develop the data which, when subsequently analyzed, confirm the adequacy of the camouflage solutions applied to the system.

6.4.2 Camouflage Performance Testing.

During the evaluation of camouflage performance, there are several areas which must be defined and considered. Much of camouflage is by nature a matter of the observers' perception. There are numerous variables. However, experience and extensive testing have proven that camouflage does improve survivability of equipment and provides an edge to those who best apply its principles. In general, the application of camouflage impact the following classifications of observation:

- Detection is said to occur when the observer correctly determines that an object of interest exists in the field of view.

- Classification is said to occur when the observer correctly determines the class of objects to which the detected object belongs (e.g., tracked or wheeled vehicle).

- Recognition is said to occur when the observer correctly determines the kind of target (e.g., tank, personnel carrier).

- Identification is said to occur when the observer correctly determines that the singular target of interest is in the field of view; i.e., he is correct in separating out the single target of interest from the class of recognized targets.

The term "target acquisition" is often used in an operational context, in which case it typically refers to the set of decisions described above under the terms detection, recognition/identification and discrimination. It is rarely the case that the observer can consciously separate these classes of response, particularly in a limited time search situation Most camouflaged targets are designed to avoid detection. In some special cases, camouflage may succeed by merely preventing the enemy from identifying the target. However, the probability of detection in a limited time search situation can generally be taken as a meaningful surrogate for probability of target acquisition in analyzing test results.

In object recognition research and testing, two other terms also are used:

- Response time: The time between the presentation of the target and the observer's response. This is often converted to range to target in the case of air-to-ground search.

- Per cent or probability correct: Usually related to detection or recognition criteria, the per cent correct, for a given situation, is an estimate of the performance of a number of observers (or a number of trials for a given observer). Often the per cent correct is plotted cumulatively versus range to the target, or versus the time the target is in the field of view. Other measures derived from this score are those of completeness (the number of correct responses divided by the number of targets possible) and accuracy (the number of correct responses divided by the total number of responses, correct and incorrect). These last two measures are most often used in photo interpretation.

This material relates closely to the theory of camouflage, which is discussed in further detail in Appendix A, for the system developer wishing further insights into this complicated perceptual area. Likewise, further contact with BRDEC is highly recommended for detailed specific questions on camouflage theory.

6.4.3 Basic Test Components.

Figure 6-2 illustrates the basic arrangement for testing camouflage performance. An essential component, of course, is the system being tested. The enemy's remote sensors are simulated based on our understanding of the threat posed to our equipment. Another key component is the observer, which is almost always a human, and the place where the decision occurs. Having a human being in the chain introduces a number of psychophysical variables, many of which are difficult to measure accurately (such as perceptual thresholds). There are, likewise, some possibly significant errors associated with this component of the test. Another component is the distance between the object and the sensor (range). Still another is the time of exposure. Both of these must be carefully regulated. Another component, and one of the most important, is the background. It is important to test the equipment under various background conditions expected on the battlefield. Examples of varying background conditions are: sandy roads, low shrub, grass, grass-trees, etc. If resources are available, camouflaged equipment should be evaluated for at least two acquisition conditions; i.e. detection and identification.

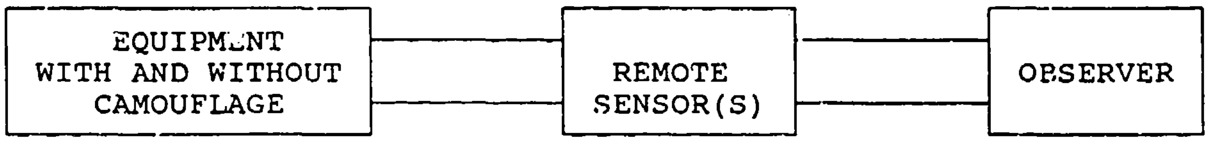


Figure 6-2. Basic Testing Arrangement.

Table C-1 lists the most important factors influencing target detection and recognition when using the human eye for observing and evaluating displayed information. Since human observers differ in native ability, search habits, motivation, etc., it is necessary to use multiple observers in a particular test series and to statistically average the results.

## 6.5 EXAMPLES OF CAMOUFLAGE TEST AND EVALUATION

### 6.5.1 Context.

This section presents two case histories of camouflage test and evaluation procedures. The first deals with the ICC (Individual Camouflage cover) which is a general purpose camouflage item for use by an individual soldier. The second relates to the IR camouflage of the Army's main battle tank, the M-1. Here, we are concerned with testing the camouflage treatment of a major Army asset.

### 6.5.2 Desert Testing of Individual Camouflage Cover (ICC).

The ICC is a personal camouflage net for soldiers which is useful for patrols, snipers and ambush situations. Desert T&E was conducted to determine the optimum ICC color and pattern incisions in terms of blending with the desert background. Twelve observers subjectively evaluated seventy-four ICCs (thirty-seven different colors combined with either large or small pattern incisions) at five desert sites. Preliminary rankings were made to reduce the number to the best twelve candidate color/pattern combinations. These were then subjected to paired comparisons which overcomes the problem of inconsistency of judgements expressed by the same observer. The observers were presented with every possible grouping of paired color/pattern combination and forced to choose between them. The data was analyzed statistically to determine the preferred color/pattern combination for each site and across all sites.

Table 6-1. Factors Influencing Target Detection and Identification.

The scene (or total picture)

1. The size of the picture or displayed image.

2. Numbers, sizes, shapes, and scene distribution of areas contextually likely to contain the target object.

3. Scene objects:numbers, shapes and patterns, achromatic and color contrasts, colors (hue, saturation, lightness), acutance, amount of resolved details, all both absolutely and relative to the target object.

4. Scene distribution of objects.

5. Granularity, noise.

6. Total available information content and amount of each type of information. This is one way of summing up 1-5 plus other elements.

7. Average image brightness or lightness.

8. Contextual cues to target object location.

The target object

1. Location in the image format.

2. Location in the scene.

3. Shape and pattern.

4. Size, color, resolution(s), acutance, lightness or brightness.

5. Type and degree of isolation from background and objects.

The test subject (Observer)

Training, experience, native ability, instructions and tasks briefing, search habits, motivation, compromise on speed versus accuracy, assumptions.

Figure 6-3 is a graphical display of the resulting statistical evaluation of the test data gathered.The vertical axis represents a number which is proportional to the number of times a particular color/pattern combination was preferred in a pairwise comparison divided by the total number of comparisons made in which the particular color/pattern combination was one of the two choices available. The horizontal axis is plotted in terms of the final twelve candidate color/pattern combinations.

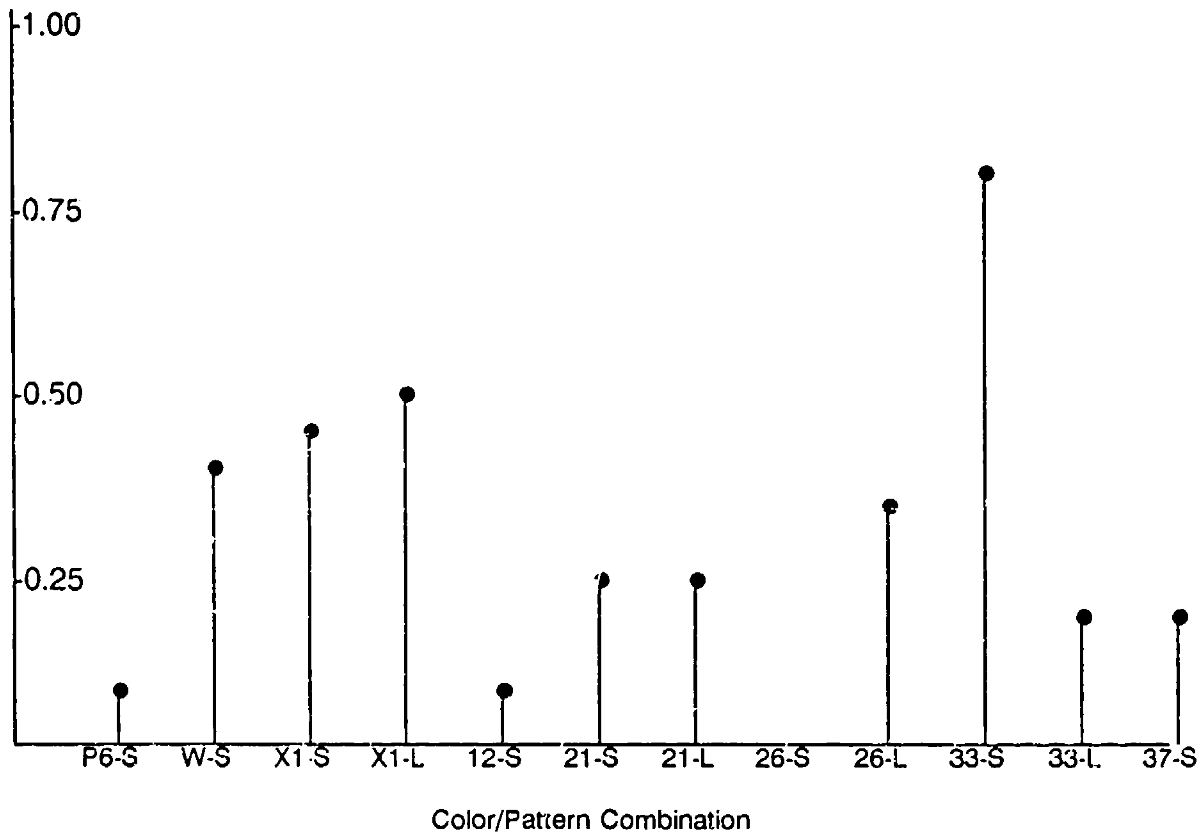


Figure 6-3. Ability of the Final ICCs to Blend with Desert Background, Averaged Across All Sites.

Color/pattern combination 26-S, having demonstrated the best blending ability, was selected for initial ICC production for desert use.

6.5.3 IR Signature Testing of Camouflaged M1 Tank.

The M1 Main Battle Tank is a major Army asset whose increased battlefield survivability is of primary concern. To achieve enhanced survivability, it is necessary to reduce the tank's IR signature and thereby reduce the enemy's ability to detect, acquire and engage the tank using IR detection sensors. During the course of the tank's development, various possible countermeasures were examined. These included: modification of operational tactics, modification of the tank's basic design to enable a reduction of the IR signature (built-in camouflage), use of add-on camouflage kits to reduce the apparent IR signature, and the possible use of IR decoys.

This process was carried out during the development of the M1 tank. Table 6-2 shows the changes in the IR test requirements of the camouflaged tank. Initially, the requirements were stated in terms of total radiation allowable (watts/steradian) in a particular wavelength band. As the threat became better defined and more measurements were made on prototype hardware, the focus of the requirements shifted to the average integrated temperature limits of various areas of the vehicle in terms of degrees centigrade above ambient. Note that in the final set of requirements, the IR radiation is stated in terms of maximum allowable temperature for each of four surface/component features.

Table 6-2. M1 IR Limiting Test Specifications.

| | |
|---|---|
| **1972-1973 REQUIREMENTS** | |
| Wavelength (μ) | Watts/Ster |
| 1.2 - 29 | 122.5 |
| 3.0 - 5.0 | 2.5 |
| 8.0 - 14.0 | 62.4 |
| **1979 REQUIREMENTS** | |
| Area of Vehicle | Average Integrated Temp Limit (° C) |
| Exhaust Outlet | 20 C above ambient |
| Remainder of Engine Compartment (including hot air grills, track and suspension) | 5 C above ambient |
| Entire Aspect of Tank (front, left, right, left, right, rear, top) | 4 C above appropriate background |
| Limit for Engine Exhaust Outlet Facet | |
| Wavelength (μ) | Non-Contrast Apparent Radiant Intensity Watts/Ster |
| 3.3 - 5.5 | 8.0 |
| **1983 REQUIREMENTS** | |
| Surface/Component Features | Max Allowable T |
| Exhaust Outlet Facet | 20 C |
| Engine Transmission Compartment Armor | 5 C |
| Hot Air or Heat Exchanger Grills | 8 C |
| Track and Suspension Integrated Average | 5 C |
| Limit for Engine Exhaust Outlet Facet | |
| Wavelength ( ) | Non-Contrast Apparent Radiant Intensity Watts/Ster |
| 3.1 - 5.5 | 2.5 |

Source: Adapted from Reference 9.

The goal of IR signature suppression is to obtain the maximum reduction in detectability at a reasonable cost while minimizing any reduction in performance. To achieve this goal, design requirements must be established based on threat assessments and tactics. As the concept matures, it is necessary to revise the test specifications so as to factor in current and future weaponry trends. At the same time, any new specifications formulated need to be realistic and supportable by existing technology.

## 6.6 AVAILABLE SUPPORT SERVICES

TROSCOM's BRDEC has the experience and personnel to assist with overall requirements, development and field use of equipment in all areas of camouflage.

For assistance, write:

Commander
Belvoir Research, Development and Engineering Center
ATTN: STRBE-JD
Fort Belvoir, VA 22060-5606

Or call:

AUTOVON: 354-6741
Commercial: (703) 664-6741
FTS: 544-6741

There are numerous test facilities available to the equipment developer and tester for testing and evaluating the effectiveness of camouflage applied to a particular system. Appendix C contains a register of many of them. Information or assistance on the use of Army test facilities for testing camouflage may be obtained by writing to BRDEC (above address) or:

Commander
U.S. Army Test and Evaluation Command
ATTN: AMSTE-TA-T
Aberdeen Proving Ground, MD 21005-5055

Or call:

AUTOVON: 298-3768/3640
Commercial: (301) 278-3768/3640

## 6.7 REFERENCES


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