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CAMOUFLAGE BY REFLECTANCE OF THE NATURAL TERRAIN

FINAL REPORT

by

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August 1972

[redacted]

ABSTRACT

This report describes a short term feasibility program to determine if a military vehicle could be camouflaged, to the unaided eye, by reflecting the natural terrain in front of the vehicle. A prototype reflective screen, weighing approximately fifty (50) pounds, was fabricated and field tested.

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Introduction

Camouflage by reflective methods has been in use for centuries as is evident in the illusions created by great mystics in the past. In those illusions, the clever arrangement of mirrors and careful control of the observer's view produced an apparent disappearance of some thing or person. In this program, an application of these techniques was used to demonstrate the feasibility of camouflaging military vehicles by reflectance.

A flat mirror, placed between an observer and the object, can be tilted backward to reflect the sky, forward to reflect the ground, or to a mid-position to reflect the observer. It is obvious that an object located on the crest of a hill and viewed by an observer from below requires a very different kind of camouflaging than one in a depression and viewed from above. Figures 1 and 2 illustrate these points. Application of this device or technique must be logically limited to those situations where the device effectively obscures the object or significantly reduces the likelihood of detection.

In this program, the General Electric Company/Ordnance Systems Division (GE/OS) considered only the frontal camouflage of a vehicle and primarily in a foliage environment. Enemy observers were considered to be at a similar elevation, at ranges of one-half (½) kilometer and beyond; the vehicle was stationary. It was assumed that tactical troops would take advantage of all natural surroundings in using the device.

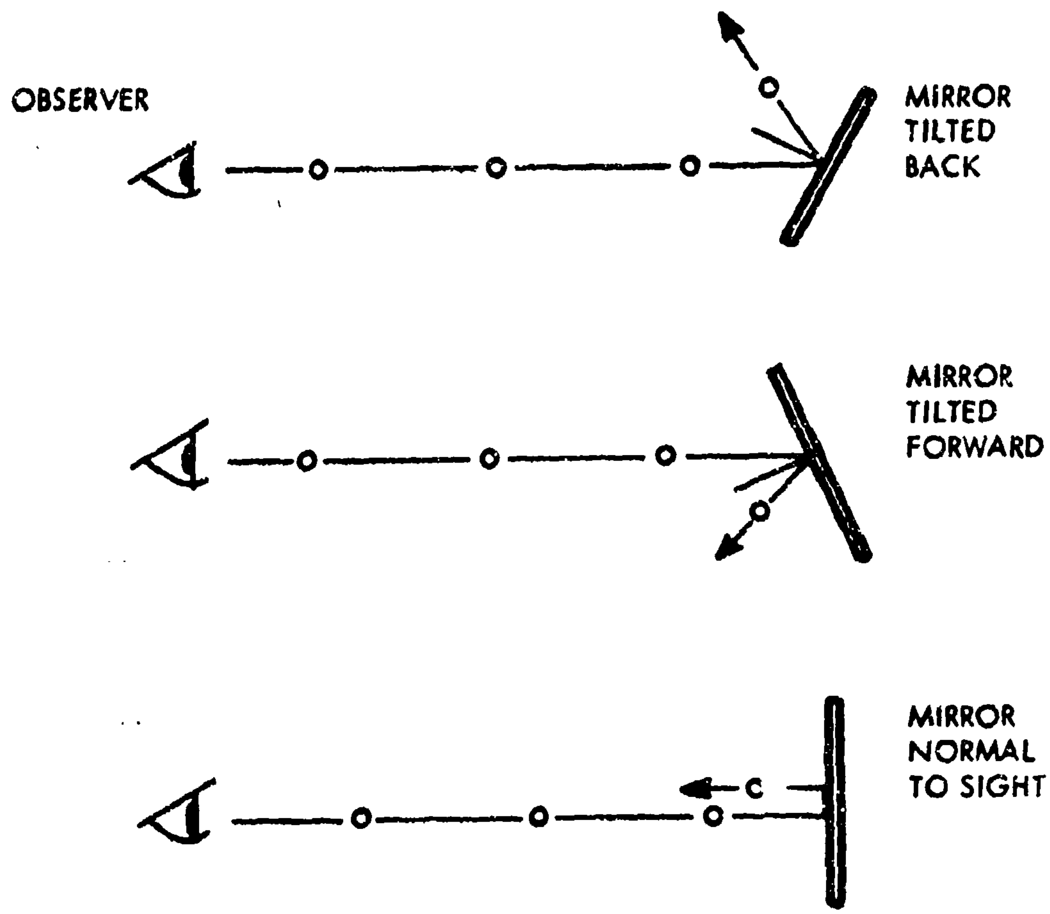


Figure 1. Effect of Mirror Angle (Elevation Views).

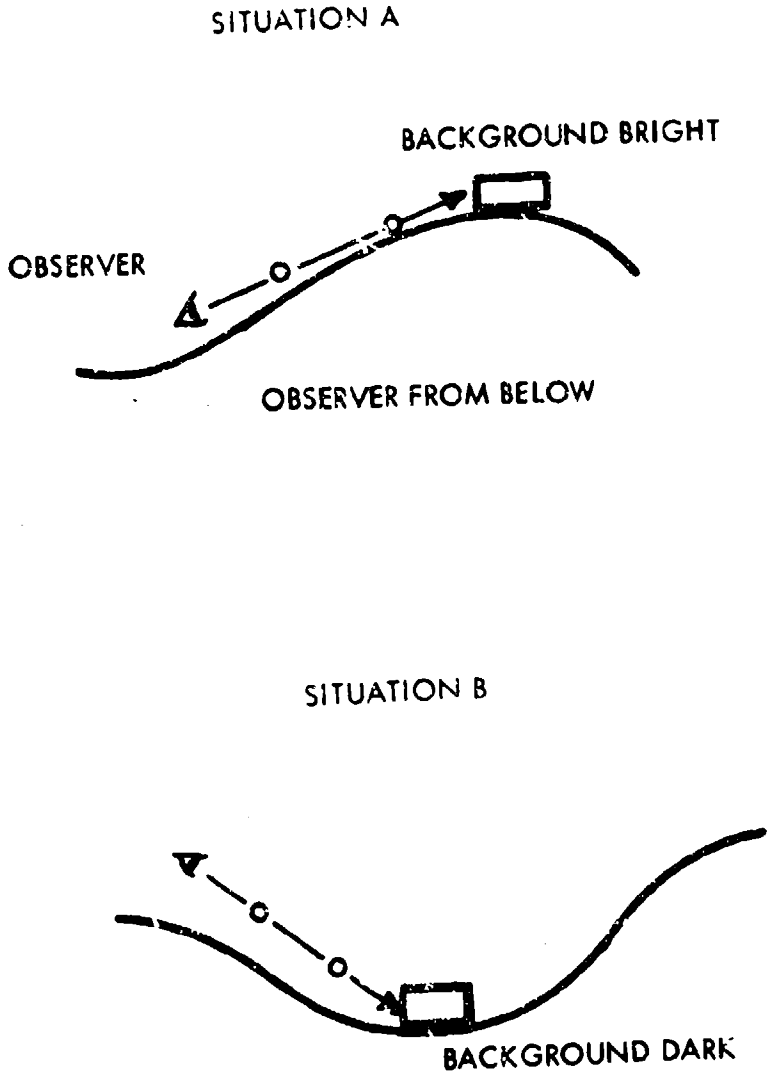
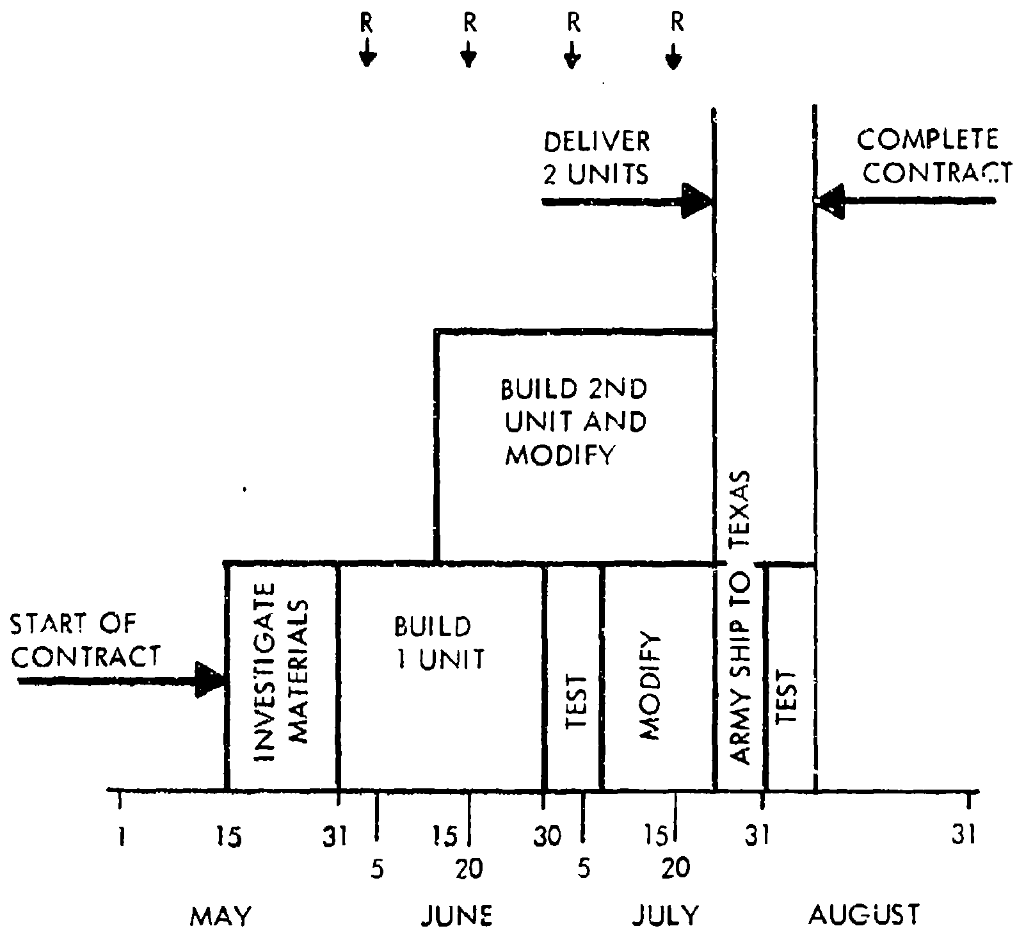


Figure 2. Effect of Background.

Schedule

The program adhered to the following compressed schedule. Two series of evaluations were held in late July and early August 1972, one at Aberdeen Proving Ground, Maryland and the latter at Fort Hood, Texas.



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Design Concept

The basic selection of reflector geometry was the first major consideration. Plane, single-surfaced mirrors offered the simplest approach. Selection of a mounting angle relative to the ground and to the observers' general line-of-sight were the essential criteria. Positioning of the mirror in azimuth was also of some concern since it can cause a shifting of the ground pattern reflection to some degree.

The use of bi-surface reflectors is a more sophisticated approach; the conventional porroprism is an illustration of this. A mirror composed of a large number of such pairs of reflective vertical surfaces, arranged alternately at 90° to one another, would provide a shield whose reflective image was less sensitive to azimuth position and to distortions of the shield. Sensitivity to elevation orientation, of course, remains the same as the plane mirror.

If the reflective shield were composed of a mosaic of tri-surfaced mirrors, each consisting of three reflectors arranged mutually perpendicular to one another, the observer's own image would be redirected to himself (this is the classical cube corner or corner reflector). Although totally insensitive to azimuth or elevation orientation of the reflectors, the image seen is not the desired one. Preformed tri-surface mosaics, having the upper surface tilted downward, could be made to always reflect the foreground into the observer's eye and still be insensitive to azimuth and elevation orientation of the shield.

Considerations were given to mounting angle, reflectivity of material, color shift imparted by reflective material, and the possible need for edge blurring of the reflector to ease the transition from real to reflected material.

During early concept stages a diorama was constructed consisting of a model jeep, "Astroturf" and samples of different types and shapes of reflective materials. This was used for early evaluation of materials, as seen in Figure 3.

Numerous possible designs of reflective shield were considered; such as a large rigid single panel, or several rigid panels folding for storage, rigid panels snapped to a frame for use, or a thin material capable of being rolled up for storage. The roll-type appeared most practical for feasibility demonstration units and quite probably also for future designs.

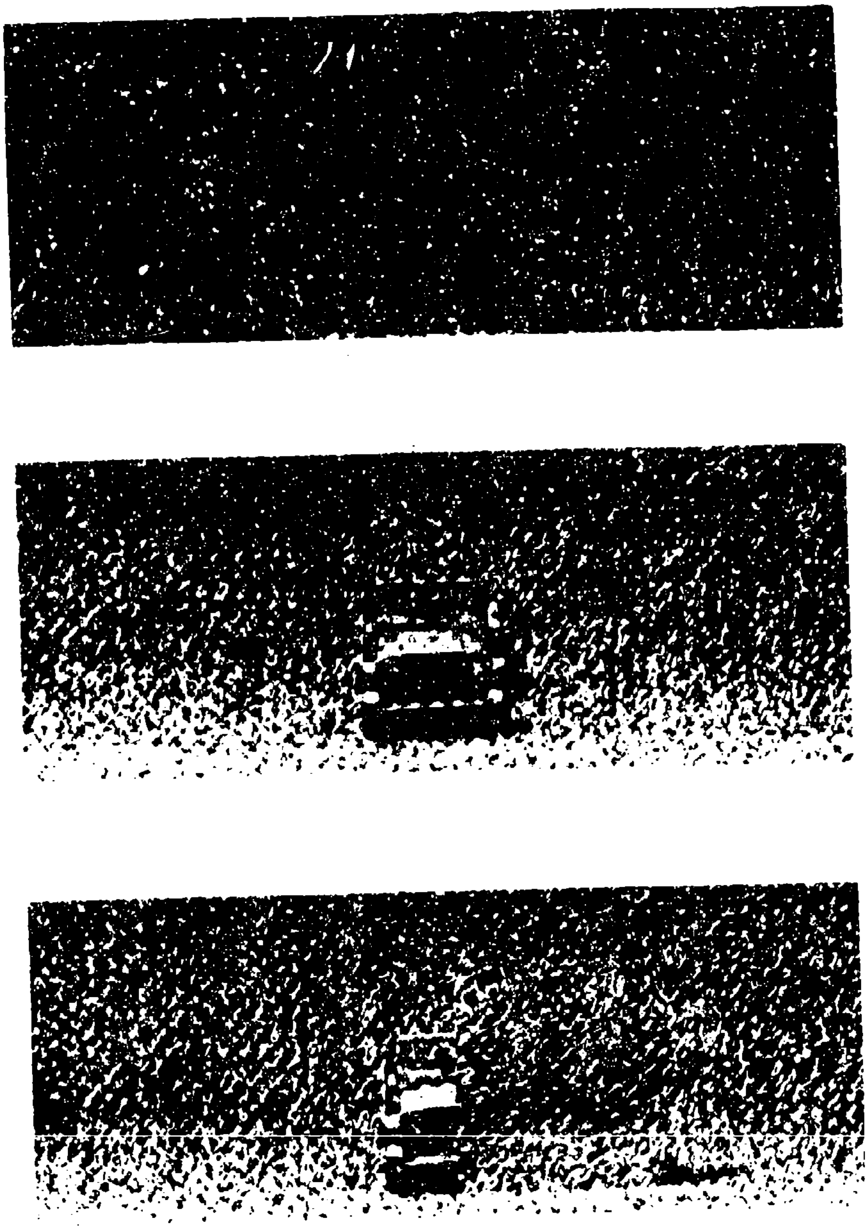

Figure 3. Diorama of Reflective Shield Concept.

The shield support design concept was one having a cylindrical storage container, equal in length to the shield width and containing a mandrel/crank and ratchet assembly on which the reflective material was attached and pre-wound. The folding vertical, top horizontal, and diagonal support members were attached to the cylinder at either end. Hook and loop fastener material (VELCRO) was cemented to the vertical support members and to the back of the shield along the vertical edges. Rear diagonal telescoping braces, guy ropes and ground pegs were attached at time of erection. These details can be seen in Figures 4, 5 and 6.

The shield mounting angle was studied for apparent movement of the image as compared to the movement of the background as an observer moved parallel to the shield surface. The ratio of these angular movements is a function of viewing distance and the distances between shield and background and shield and reflected foreground. The curves are shown in Figure 7. and are seen to vary as the ratio of the image to the viewing distance varies. A ratio of unity is ideal and the greater the ratio the more likely is the camouflage to be detected. The effect is much greater for the bi-surface materials. This becomes of little real concern since the most likely operating angles selected, as Figure 7 indicates, will have ratios of 1 to 2½ with no significant difference between surface arrangements.

Maintaining flatness on a single reflective surface is of some importance since distortion of the surface, as by wind, results in "fun house mirror" images and is detectable when viewed at moderate distances. Figure 8 illustrates the expanding and compressing distortion of the image as the shield suffers distortions. Figure 9 shows that an image created by the bi-surface material is constant in size, merely reflecting from different elements of the shield as it distorts. Although not optically desensitized to distortion in the elevation plane, the material becomes significantly stiffer as a result of the corrugated configuration and less likely to distort.

Material reflectivity is also a significant factor. Preliminary field tests using low reflectivity (approximately 55%) chromium resulted in easy detection at moderate distance due to the grayness of the image. Substituting aluminum of 85% reflectivity caused the sample to vanish, even at 50 feet. The curves in Figure 10 show the effect of shield construction on the required material reflectivity, the bi- and tri-surface construction requiring higher reflectivities which are more costly and more difficult to obtain. Also to be considered was the color selectivity of the reflective material. Any "tint" to the material is an indication of its preferred color reflectivity and must not be permitted in the choice of material. Figure 11 is representative of the Beckman spectrophotometer measurements of reflectivity vs wavelength (color) for two samples of the aluminized Mylar that were selected as the shield material.

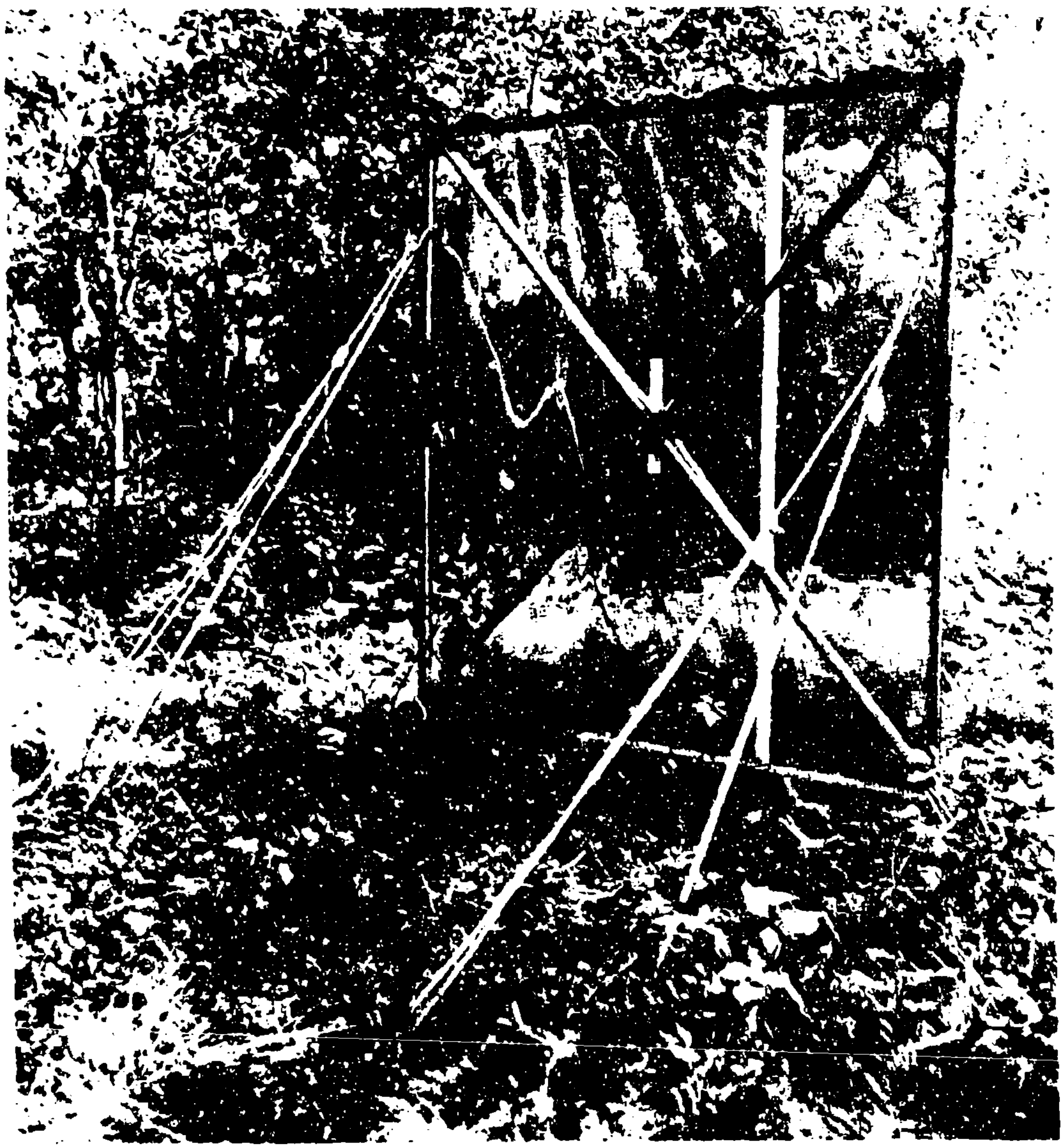

Figure 4. Rear View of the Erected Prototype Reflective Shield.

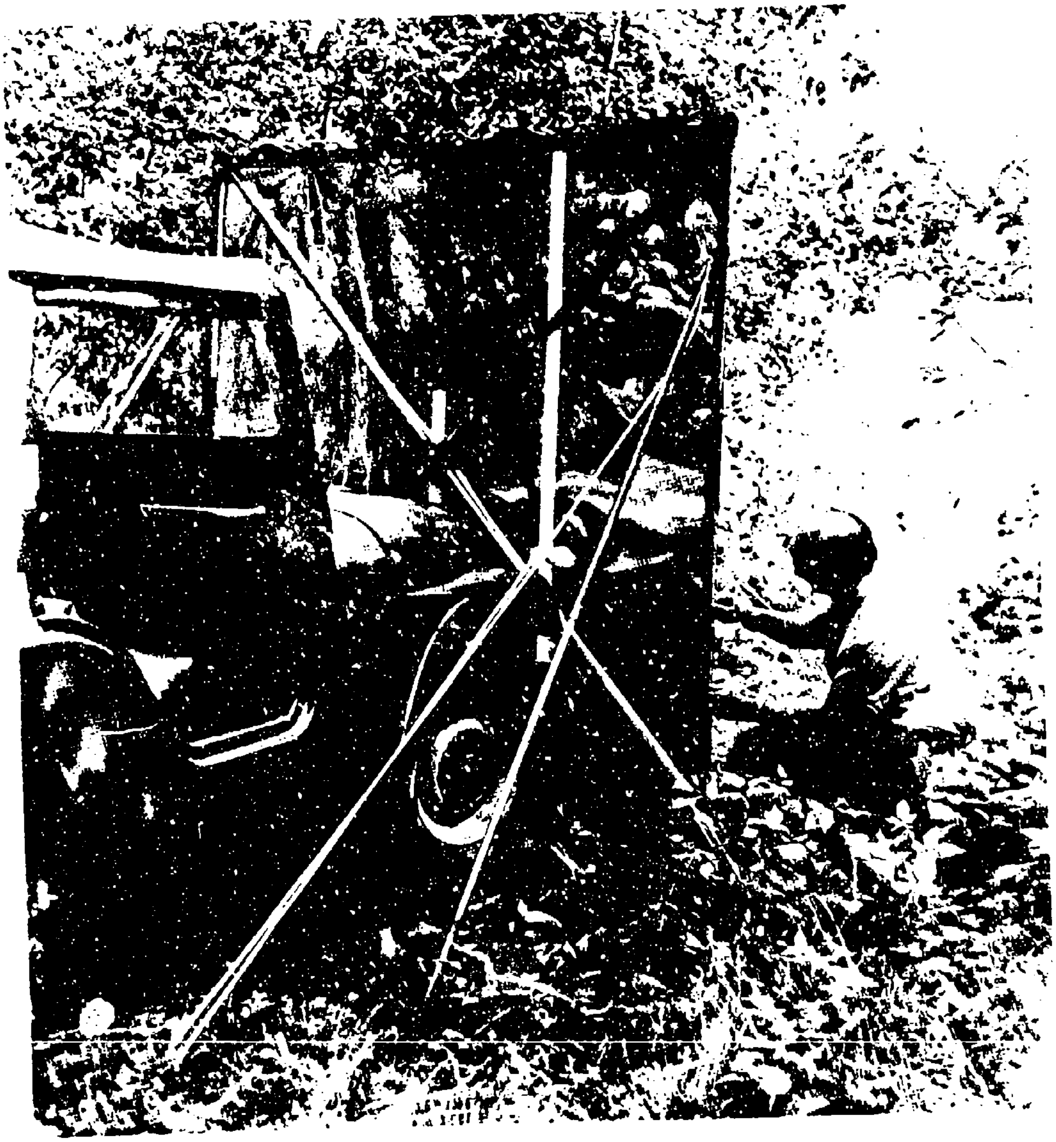

Figure 5. Rear View of the Prototype Reflective Shield Camouflaging a ¼ Ton Vehicle.

Figure 6. Front Surface of the Reflective Shield.

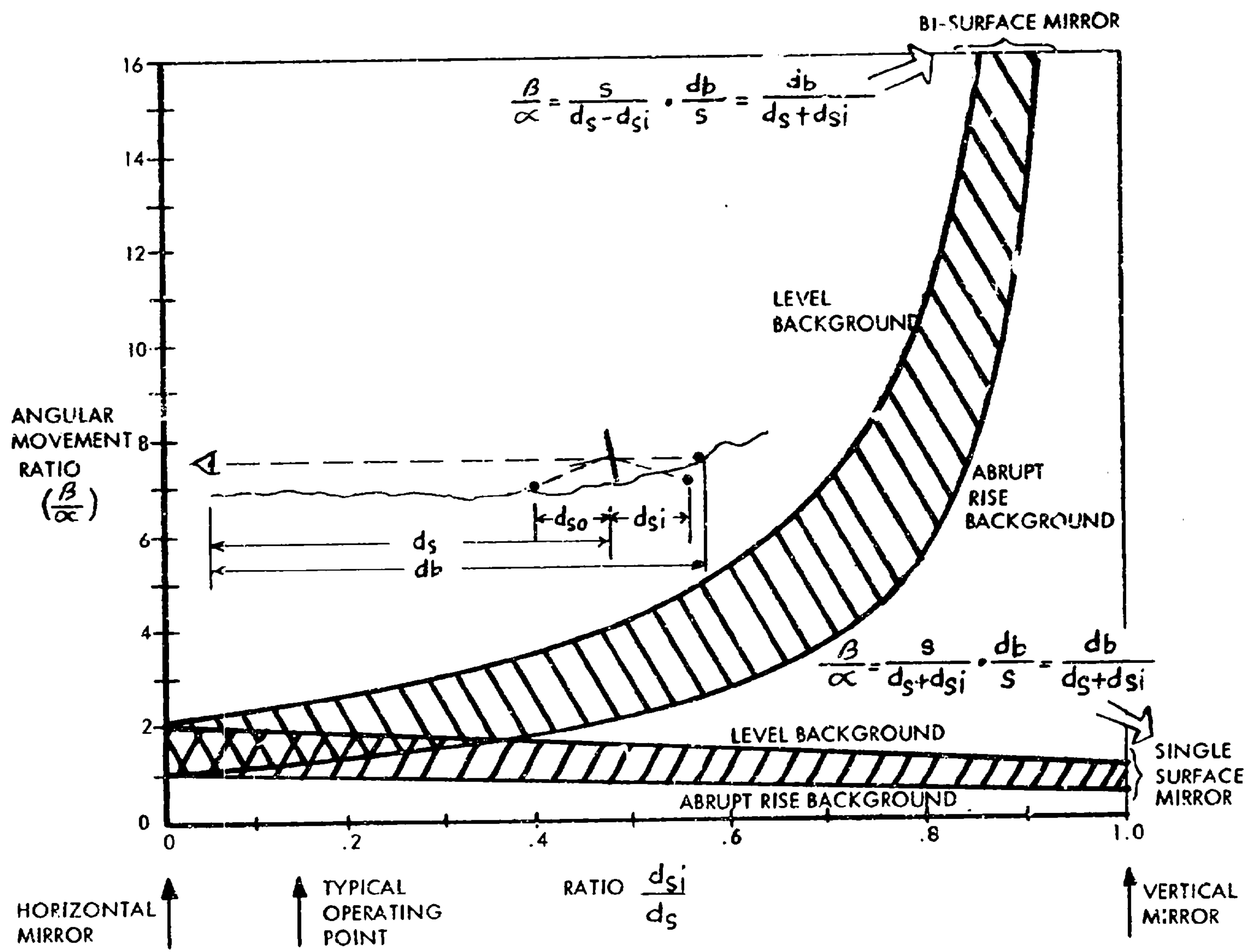

Figure 7. Effect on Angular Movement Ratio on Image to Background as a Function of Mirror Tilt.

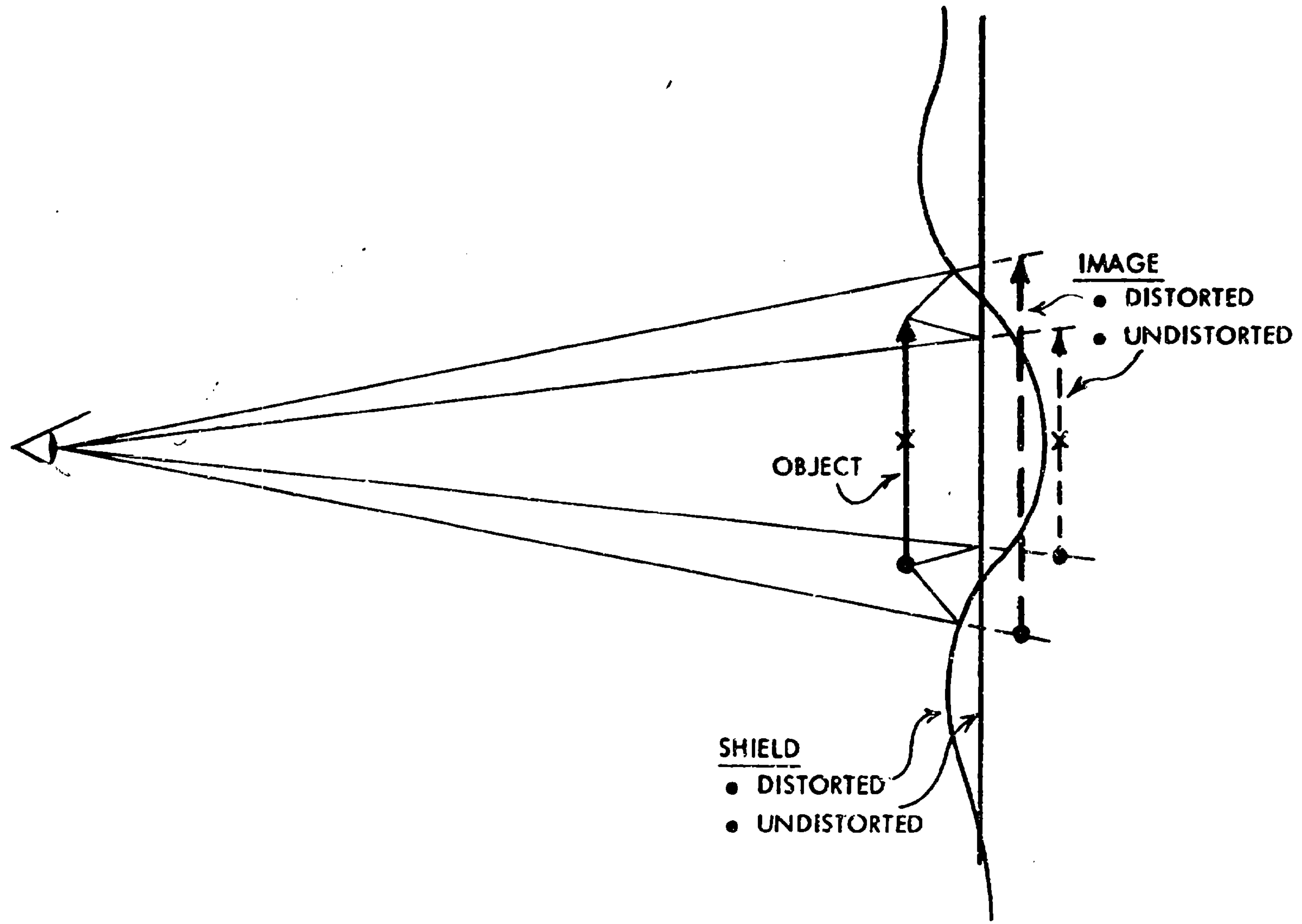

Figure 8. Effect of Wind (Mirror Curvature) on Image Formation Using a Single Surface Reflector.

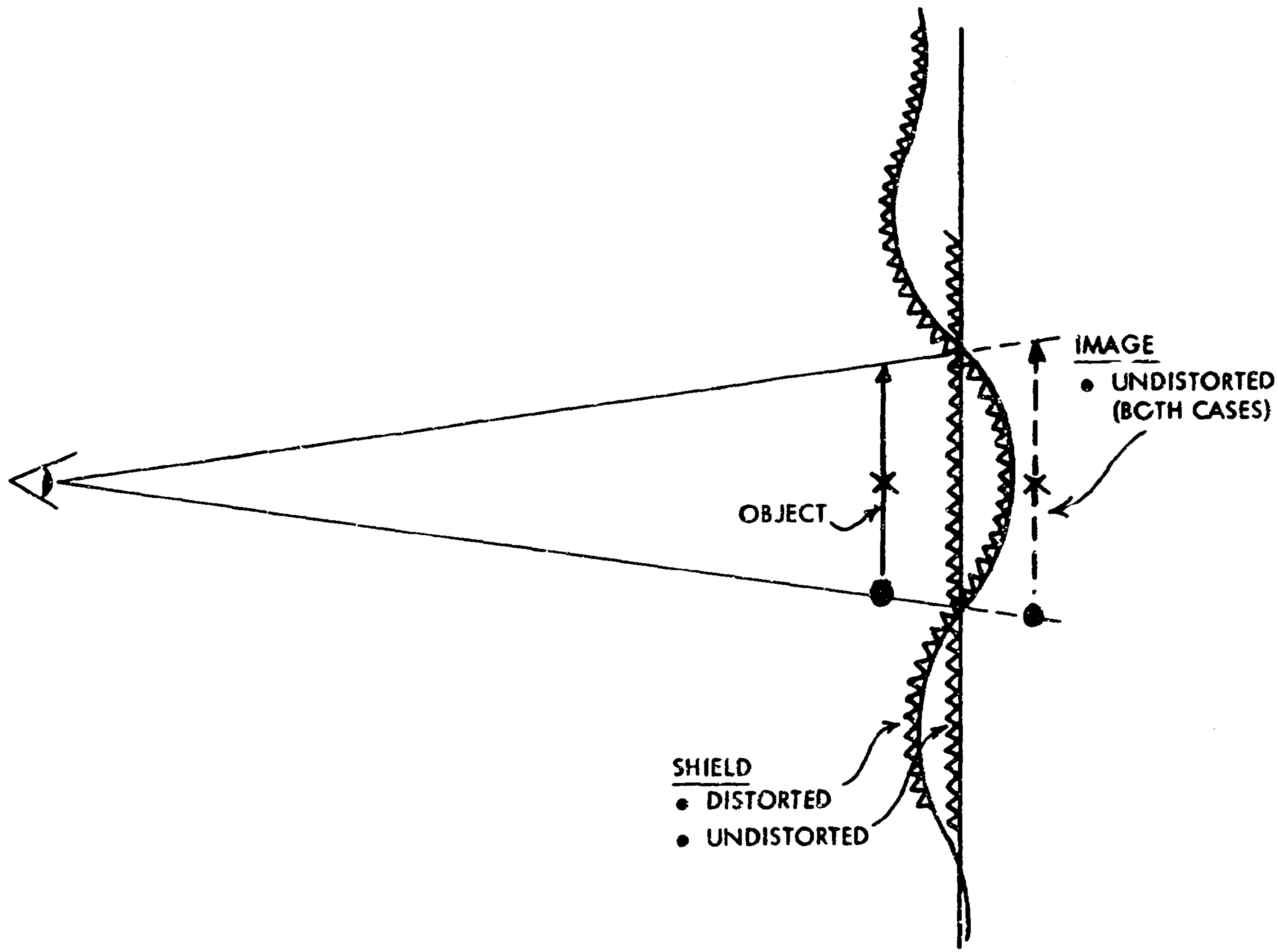

Figure 9. Effect of Wind (Mirror Curvature) on Image Formation Using a Bi-Surface Reflector.

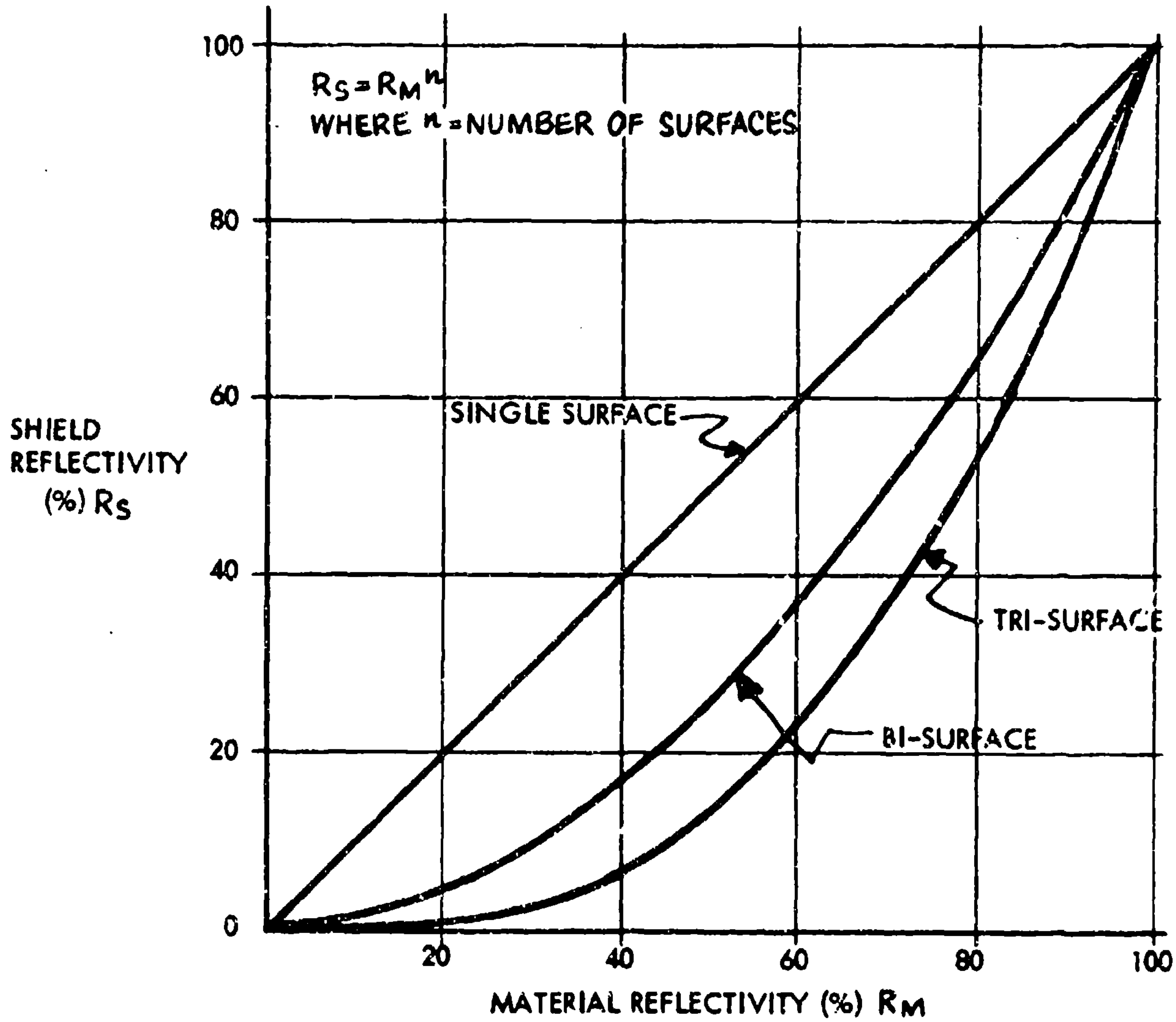

Figure 10. Effect of Materi l Reflectivity on Reflectivity of Shield Assembly for Single & Multiple Surface Constructions.

A removable sight was designed and provided to permit selection of the proper mounting angle from behing the shield, rather than having personnel exposed during the set-up operation. It consisted of an optical sight with 1:1 magnification, and having cross-hairs included for centering. The sight was swivel mounted on a horizontal axis to a plate which could be easily attached or removed from one of the vertical support members. The sight was equipped with a mechanical stop, placing it at an elevation of 90° to the shield. When the sight was tilted a pointer on the telescope objective barrel indicated the amount of tilt on an adjacent calibrated scale.

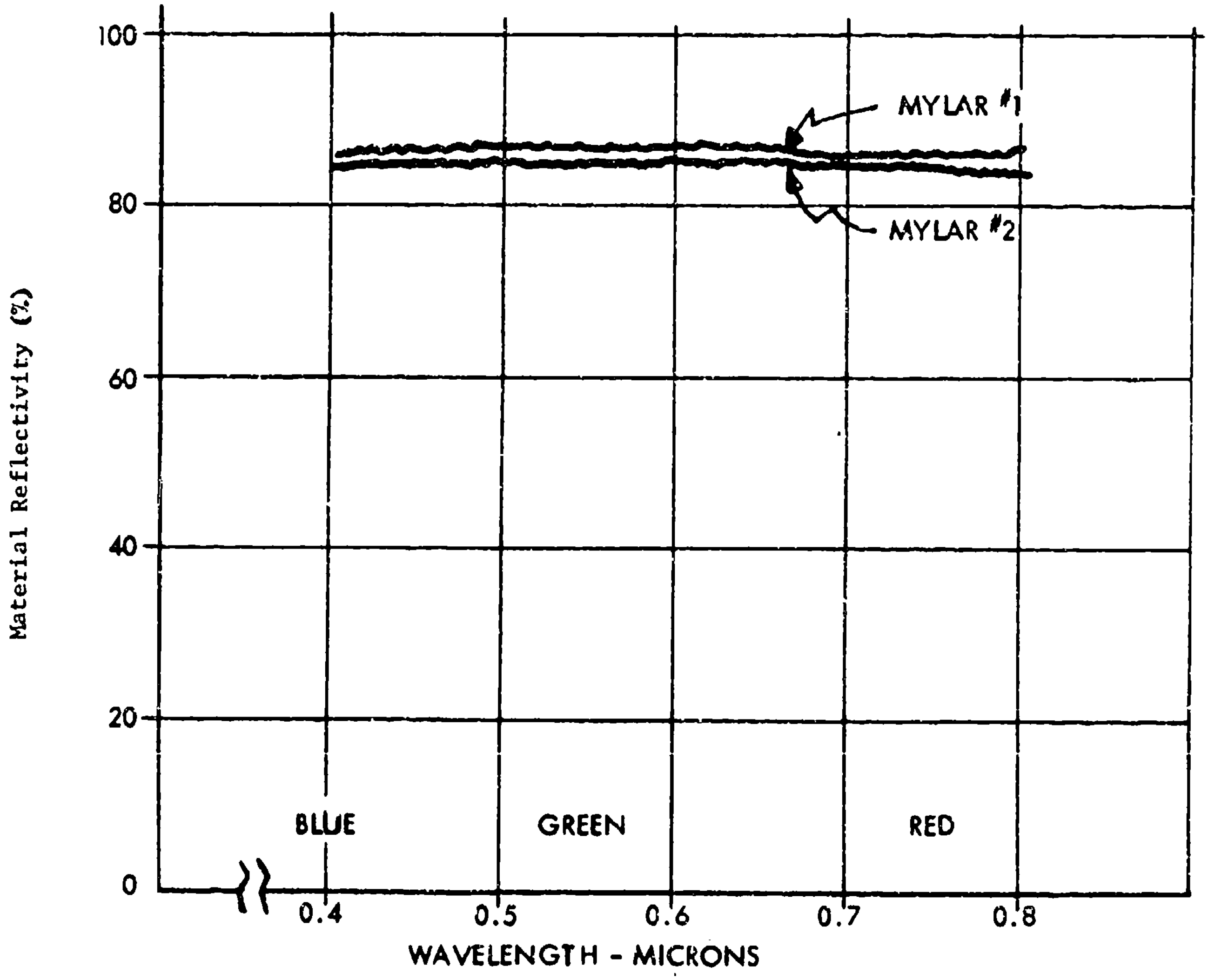

Figure 11. Effect of Color of Light on Reflectivity of Aluminized Mylar Material.

Material Search

Materials and vendors were explored for the single surface reflective approaches with accent placed on the properties of high reflectivity, durability, reasonable cost and rapid delivery. The latter two items were of prime importance because of the tight cost and delivery requirements for the feasibility units. Lexan* (a polycarbonate) and Mylar** (a polyester) offered the desired properties for a substrate. Mylar was available commercially, it was aluminized, and was packaged in wide rolls. Delivery schedules of the material limited the selection to a single vendor, Kury-Hastings and Company, Dutton Road, Philadelphia, Pennsylvania. Unfortunately, they could supply only one size (.005 inches thick and 56 inches maximum width). Two sheets of material had to be butted and held together with a Mylar supported adhesive tape to achieve the required 84-inch width. Other vendors could provide greater widths and thicknesses (up to .020 inches) with higher reflectivities but larger minimum quantities were required because of special order. These sources should be considered in future work.

Bi-surface materials could not be obtained commercially and a small scale molding operation was set up to fabricate samples for study. Refer to the section on Process Development for Bi-Surface Material.

Tri-surface materials were not commercially available and, although single tri-surface models were molded at GE/OS, there appeared no economically feasible way (within the time and cost framework of the contract) to prepare a mosaic of these.

Process Development for Bi-Surface Material

The Process Development Laboratory of GE/OS has a wide variety of vacuum forming and molding presses equipped with heat and pressure with which numerous plastic materials can be shaped and formed. In addition, it has vacuum deposition equipment for applying highly reflective coatings of most metals. Male and female molds were made, approximately six inches square, having the desired bi-surface contour of multiple flat surfaces alternately 90° to one another. The problems associated with making the mold were in achieving sharp 90° peaks and valleys and in achieving well polished surfaces. Either of these faults resulted in the reflective shield picking up a diffuse skylight reflection, spoiling the camouflage effect. Ultimately a satisfactory sample was made and field tested on a small scale. The most successful samples were of Lexan formed under pressure of 50,000 psi followed by a short heat cycle. This was followed by vacuum deposition of aluminum over a base deposition of chromium. Others were made of the 5-mil aluminized Mylar, again using 50,000 psi and heat. The Lexan sample was used in the diorama (see Figure 12) shown at LWL for demonstration purposes.

* Trade name of the General Electric Company
** Trade name of E. I. DuPont de Nemours & Company, Inc.

Figure 12 of the diorama was made using an early sample which was imperfect along the sides. This, however, is the only photograph available. The principle of the bi-surface configuration was established as successful and, if desired, future work could be done with plastics processors to determine the possibilities of producing rolls or large sheets.

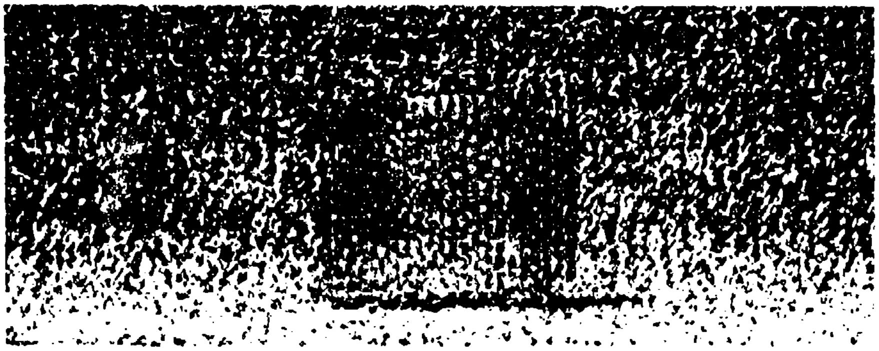

Figure 12. Diorama with Experimental Bi-Surface Reflective Shield.

Shield Fabrication

The Process Development Laboratory fabricated and assembled two shield assemblies. The only significant problems were in finding compatible adhesives for joining the Mylar to itself or to the steel or aluminum members and being capable of withstanding backwind tension over extended periods of time. Thermosetting adhesives could be compounded to overcome this. A riveted sandwich construction was employed to attach the Mylar to its rigid header, to reduce the load on the adhesive.

Field Testing at GE/OS Vehicle Testing Grounds

The first shield was field tested at the GE/OS Vehicle Testing Grounds in Pittsfield, Massachusetts. The main objective of this test was to determine the effectiveness of the shield to camouflage the front of a ¼ ton military vehicle at a range of 500 meters or less under a variety of terrain conditions. Further objectives of the test were to (1) develop a preliminary operational use concept; (2) check the design of the shield and (3) take pictures to be used for training purposes. The tests were conducted under a variety of conditions ranging from open, grassy fields to the edge of moderately dense wooded areas. Bright sunshine and cloudy days were encountered during the testing days in June and July 1972.

The field tests successfully demonstrated the feasibility of the prinicple. Minor shortcomings were found when the Mylar adhesive slipped slightly, allowing the Mylar to ripple and distort the reflection in a close-up view. It appeared desirable to have a sighting device to permit personnel to easily tilt the shield to the desired angle. In addition, it was found that a cross-wind would cause distortion of the shield and its image. Stiffer material would be a solution but this was not available. Alternatively, a polyurethane foam sheet of approximately 1/8" thickness was applied to the back of the Mylar of both shields. Subsequently the second shield and sighting device were field tested with satisfactory results. Although the shield was not totally free of wind effects, it was markedly improved.

Delivery and Demonstration at Aberdeen Proving Ground

The two shield assemblies were delivered to the U.S. Army Land Warfare Laboratory at Aberdeen Proving Ground, Maryland on 27 July 1972. A demonstration was presented to civilian and military personnel from USALWL and USAMERDC, Fort Belvoir, Virginia. The demonstration consisted of emplacing one of the reflective shields in front of a ¼-ton vehicle that was parked in flat terrain at the edge of moderately dense woods. A second uncamouflaged vehicle was placed near the camouflaged vehicle in the same tree line. Markers were placed in front of the camouflaged vehicle every fifty meters out to a viewing range of 250 meters. The weather was humid and alternately overcast or sunny. Although it was 1:30 P.M., direction was of no significance since shadows were soft or non-existent. There was a slight breeze. The group advanced toward the vehicle from a distance of 250 meters, pausing at 50 meter intervals to scan the scene; but not until at 50 meters did any of the group indicate the shield was spotted. On command, the jeep driver backed away from the shield, exposing the vehicle's location. The evaluation of feasibility was confirmed. The units were repacked in their canvas covers and readied for delivery to Fort Hood, Texas.

Fort Hood Demonstration

The 1 August 1972 Fort Hood demonstration was made in conjunction with a camouflaging update briefing. The shield was set up approximately 150 meters from the observation area in a depression near a drainage ditch. The only vegetation useful for camouflage were several clumps of willows growing at the edge of the ditch; all of the surrounding area was mowed grass. One clump was selected and the shield positioned in front of a jeep with the reflected image of the willow clump projected back upon itself. The view was to the east, in bright sunlight; the time, 10:30 A.M., a 20 mph west wind was blowing. The observing party was invited to find the camouflaged jeep and after two unsuccessful selections, the jeep was backed away from the shield, exposing the location. The demonstration was effective and successful.

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13. ABSTRACT

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