APPENDIX F

WEATHER EFFECTS ON ELECTRO-OPTICAL SYSTEMS

Army battlefield capabilities have improved significantly in recent years due, in part, to the development and deployment of E-O systems. A great variety of these systems are in the Army's inventory and more are being programmed. Basically, E-O systems enhance the Army's battlefield reconnaissance, target acquisition, and target destruction capabilities.

They enable ground and aviation units to see better and accurately strike the enemy day or night even during limiting weather conditions. Since the weather parameters affecting E-O devices are numerous and the use of E-O systems is so widespread, they deserve special attention as a separate category of tactical systems.

CLASSIFICATION OF ELECTRO-OPTICAL SYSTEMS

E-O systems are classified as active (overt) or passive (covert). Active systems emit a detectable wavelength signal, while a passive system senses emitted or radiated energy. E-O systems include image intensifiers, infrared imagers, laser designators, and low-level-light (LLL) television (TV). To fully understand how weather impacts these systems, we need to know their basic operating principles.

NVG are an example of passive image intensifiers. They use extremely LLL sources (starlight), and amplify that light so that objectives are visible. These systems operate in the visual and near-infrared wavelengths.

LLL TV is a passive system and is capable of picking up targets at light levels below those usable to the human eye. This TV electronically enhances the video signal and makes it visible to the operator. Night sights, heat seeker munitions, and infrared detector munitions are examples of passive infrared imaging systems.

These systems are characterized as near infrared (short wavelength) or far infrared (long wavelength). For infrared imagers to function properly, there must be a temperature or thermal contrast between target and background area (signature). They can tell the difference between target "hot spots" and the rest of the target itself, like a warm engine in a cold truck.

Laser designators are active systems. They are used with smart munitions capable of receiving reflected laser light. The designator "pings" a target with a laser beam at a specified wavelength. The receiver in the munitions recognizes the reflected beam and homes in on the designated target. These designators do not emit light in the visible spectrum and, therefore, cannot be easily seen or detected.

When combined with E-O guided munitions, the transmitted laser beam reflecting off the target greatly enhances the delivery accuracy over conventional delivery techniques. However, the E-O guided munitions must receive the reflected beam in time to make course changes prior to hitting the target. If the beam is not reflected off the target or transmitted, or reception is disrupted, a miss will probably result.

Figure F-1 illustrates the portion of the light spectrum used by the different categories of systems employed by the Army.

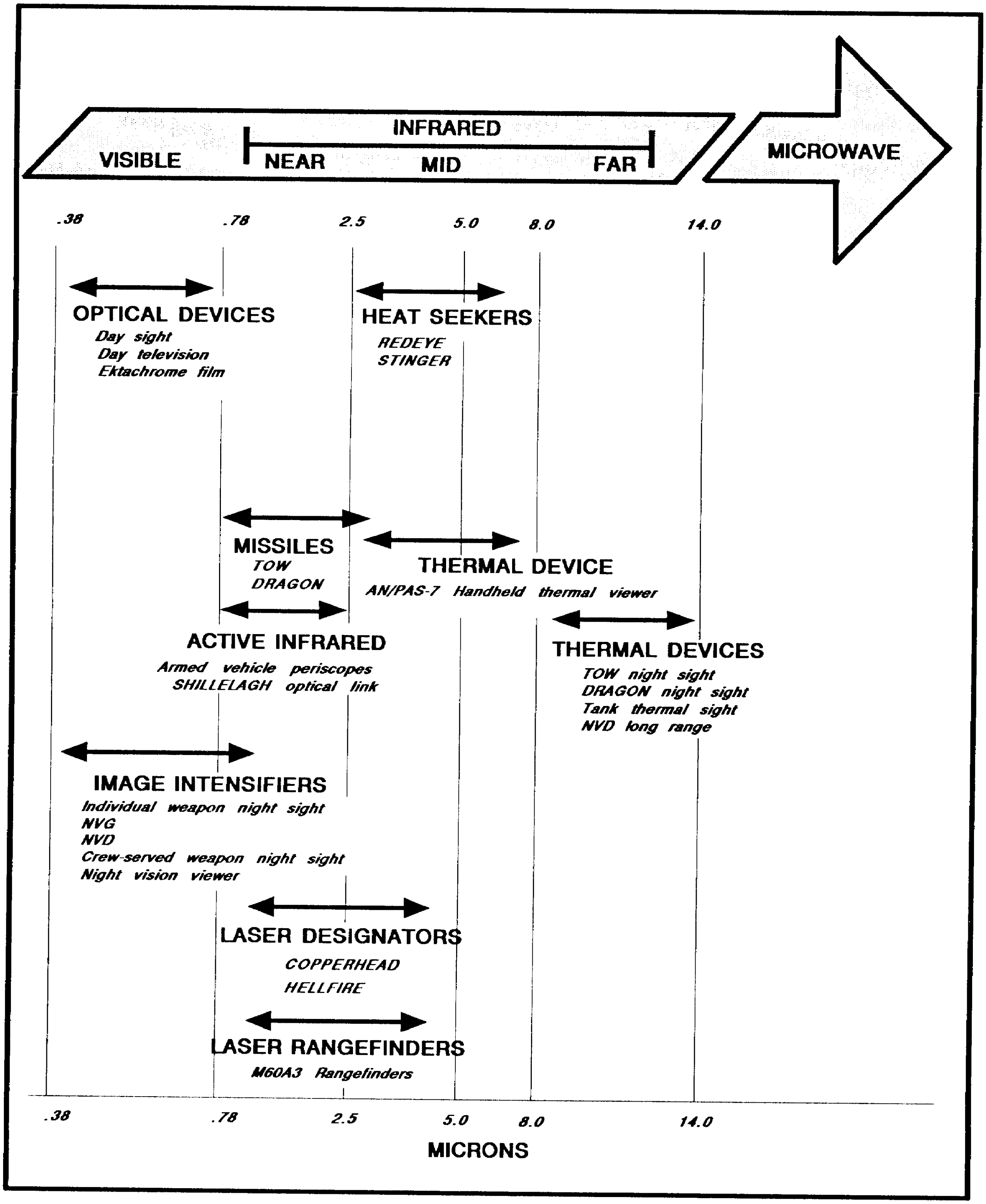

Figure F-1. Microwave ranges of selected Army E-O systems.

ENVIRONMENTAL IMPACT

The performance of E-O systems depends on three basic factors:

- E-O characteristics of the target and its background on the battlefield.
- The atmosphere between the E-O system and the target and its background.
- The sensitivity of the E-O detector system (to include human operator performance).

Weather conditions affect the first two factors, both directly and indirectly and are summarized in Table F-1. The most fundamental environmental conditions inhibiting E-O signals are--

- Attenuation or reduction of the signal by atmospheric moisture such as clouds, precipitation, fog, and high humidity.
- Temperature affecting atmospheric refraction near the surface.
- Temperature contrast between the surrounding environment and the target.
- Winds kicking up dust and sand.
- LLL.

Table F-1. Weather effects on E-O devices.

	SEVERE DEGRADATION				MODERATE DEGRADATION			
ENVIRONMENTAL PARAMETERS	VISIBLE	INFRARED			VISIBLE	INFRARED		
		NEAR	MID	FAR		NEAR	MID	FAR
CLOUDS								
ALL TYPES	X	X	X				X	X
FOG	X	X	X	X				
PRECIPITATION								
LIGHT TO MODERATE RAIN OR SNOW					X	X	X	X
HEAVY RAIN OR SNOW	X	X	X	X				
AEROSOLS (SMOKE, DUST, SAND)								
MODERATE DENSITY	X	X					X	X
HEAVY DENSITY	X	X					X	X
WATER VAPOR								
HIGH HUMIDITY (GT 80 PERCENT AND NEAR A SOURCE OF WATER)	X	X					X	

In addition to TV and binoculars, visible light systems include the TOW day sight and image intensifiers such as the individual-served weapon sight and the tank gunner's periscope. Systems that use available light are the easiest to defeat with obscurants such as haze, smoke, dust, and precipitation because visible light has a short wavelength and can be more easily attenuated.

As the wavelength of the light spectrum used by an E-O system increases, the less it is affected by obscurants. However, the long wavelength E-O system provides less target resolution. Near infrared systems like the handheld thermal viewer can penetrate some light fog oil and diesel oil smokes. Far-infrared systems, such as thermal sights for the Apache helicopter, Ml tank, TOW, and DRAGON, use longer wavelengths of the spectrum and can penetrate low densities of WP smoke and other obscurants that defeat both visible and near infrared.

In addition to attenuation from an obscurant, E-O devices are also affected by atmospheric refraction. Basically, the sun's heating of the surface air creates sufficient vertical motion or turbulence to cause this effect. A mirage is caused by this heating and can make a building appear to move or even cause a target to disappear altogether. Such apparent displacements can lead to target misses.

Although these refractive conditions are associated with periods of high heat, this condition has been observed over a snow cover when the air temperature was 25 degrees below zero Fahrenheit. The higher you are from the surface, the less likely you will encounter mirages.

Other parameters that impact on many E-O systems are weather conditions affecting the level of illumination. Although the level of light affects all devices operating in the visible spectrum, image intensifiers are influenced the most. Too much or too little light adversely affects the use of NVD.

On relatively clear nights with a near full moon, you can normally operate without the aid of NVD. With less than a full moon, there may still be too much light.

Too much light, when amplified by NVD, saturates the viewing area as seen through the device and makes the device unusable because light and dark contrasts are no longer possible. When illumination is limited, NVG must be used. For partial or heavy overcast skies with little moonlight, even these light levels may be too low to use NVG.

Additionally, terrain influences on available illumination must be considered. Even though illumination may be adequate to support the use of NVD, flying in a valley with shaded areas may end disastrously.

CLOUDS

"Smart" weapons such as COPPERHEAD and the air-launched HELLFIRE have critical cloud ceiling values. If these weapons pass into a cloud, they will lose "lock on" and miss their laser-designated target. Another system affected by low clouds is SADARM. Using E-O detectors, SADARM searches in a circular pattern at a fixed angle. As these munitions descend, the area they see becomes smaller. Low cloud ceilings drastically reduce their target search areas and time.

THERMAL CONTRAST

Millimeter wave and infrared E-O devices require a temperature difference between the target and its background. Bad weather can limit system performance. As the contrast diminishes, a condition is reached where the target is no longer discernible from the background and target acquisition becomes a problem.

Thermal imagers produce images of targets in scenes, somewhat similar to those seen on ordinary TV. The major difference is that, instead of observing light (visible energy) in the scene, thermal imagers observe heat (infrared energy) emitted, reflected, or generated by the objects in the scene.

The amount of infrared energy is determined principally by the object's temperature, its surface reflectivity, and its structural properties. Natural infrared energy is produced when objects absorb sunlight. Winds can change the image contrast by making target and background closer to the same temperature.

Man-made energy, particularly in vehicles, results from the heat of fuel combustion and the friction of moving parts. Infrared energy is not as greatly diminished at night as is visible energy. Thermal imagers tend to function as well or better during nighttime than during the day. For this reason, they are often used as night sights.

A target may be acquired with a thermal imager only if the amount of infrared energy of the target is sufficiently different from that of the background. This difference, called thermal contrast, is the difference between the temperatures of the target and its background.

Wind, rain, snow, humidity, and clouds reduce the temperature contrast between target and its background and even cause thermal reversal where instead of a "hot" target against a "cold" background, you find a cold target against a hot background. This can occur in the early morning and late afternoon when a thermal sight encounters a condition where some inactive targets without an internal heat source will warm up or cool off to the same temperature as the background.

In this instance, thermal devices will not be able to see targets because the difference in temperature is not enough to be detected. The sensitivity of the thermal device to the difference in temperature and the rate at which a target is heating or cooling will determine how long this "thermal crossover" will occur.

Most metal targets heat up or cool off faster than the ground and vegetation in the background. At night a metal target appears to be colder than the background, but with the sun shining on it, the target appears to be hot compared to the relative coolness of a background of trees or bushes.

In bright sunshine, the thermal crossover period may be just a few seconds. On cloudy days, however, the thermal crossover period may be a number of minutes. When this happens, optical sightings must then replace the infrared devices. Listed below are weather elements effecting thermal contrast at crossover time.

CLOUDS. Clouds will reduce the thermal contrast. Lower and thicker clouds have a stronger influence than higher or thinner clouds.

SURFACE WIND. Wind causes the temperatures of both the target and background to become closer to the air temperature, and as a result, closer to each other.

HUMIDITY. Moist air does not enhance the rate of cooling as much as dry air. With high humidity and a moist background, the thermal contrast would be minimal between target and background. If the air was dry, the cooling influence on the moist background would cause a greater thermal contrast.

PRECIPITATION. Falling rain and snow have cooling effects that bring target and background temperatures closer together. In the case of operating vehicles, the temperature contrast may be increased since the precipitation will have little effect on the heat generated in the engine compartment and the exhaust.

The relationship between weather effects and E-O systems is very complex since the result is a function of the precipitation particle size and the wavelength of the E-O system.

ELECTRO-OPTICAL SUPPORT PRODUCTS

You obtain E-O support from the SWO. These products identify periods of time during which NVG can be effectively used. In addition to E-O, your SWO has other predictive products that you might need. Check with him for a list.