experiments will lead, and whether the results will have practical application, we do not know. We believe that colored radar shows great promise, especially to the military, but the potentialities of such a system are only vaguely understood.

Time and work are needed to produce the answers to the questions raised by these experiments. Before successful culmination of the problem can be realized, a concerted effort will be required to investigate the photographic, electronic, and psychological aspects involved. Our experiments have given us but a glimpse of the impact a multi-color system will have on a radar-observer and his reactions. We are confident that such a system is the next step in the evolutionary ladder of detection and surveillance.

Elements of Photographic Interpretation Common to Several Sensors

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ABSTRACT: *Interpretation of radar and infrared photography involves the same basic elements utilized in the interpretation of visual photography. Regardless of origin or display represented, a photograph is nothing more nor less than a graphic record of energy intensity. While it is customary to think of the energy source in the range of visible, or infrared, light, other portions of the spectrum should not be buried in an aura of mystery. When a photograph is accepted as a graphic record of energy intensity, it is logical to extend the interpretation principles developed with visual photography to the records produced with other sensors.*

TODAY, and every day, photographic interpretation exerts a tremendous influence on almost every individual in society. Everyone is bombarded by increasing numbers of photographs. Newspapers, magazines, billboards, and television all offer photographs to look at, and from each of these photographs certain impressions or ideas are gained. These impressions are actually photographic interpretations. Such interpretations may be conscious or unconscious, accurate or inaccurate, complete or partial, but interpretation is an essential part of the process through which information is obtained from the photograph.

To place photographic interpretation in proper perspective, it is helpful to begin at the very dawn of civilization. One of the first steps in the growth of civilization must have been the development of communication. Until man could communicate his ideas and desires to other men, the concert of action necessary to form tribes and to create governments could not have taken place. People may argue about the order in which communication media developed, but all agree that drawings came early. Man's first drawings may have been finger markings in the dirt which approximated the shape of things that he had seen. When some indication of size, or scale, was added, his drawings became more meaningful. Color and indications of fur, hide, or texture have been found in early drawings of the cave man indicating that the importance of these qualities was recognized at an early date.

As man and man's civilization was advanced, his ability to communicate was improved. Languages became more expressive and drawings more detailed. Such things as shading and shadows, repetition of patterns, and combinations of related features were added. Despite these improvements man's graphics were not good enough. Man wanted a complete picture of what he had seen, and he kept searching for some way to record what his eye actually saw.

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The search for better graphic records led to the photographic process. Cameras and their graphic records have come a long way since Daguerre produced his first photo-sensitive plate in 1839, but the search for better cameras, better pictures, better graphic records goes on. Today use is made of invisible forms of energy to produce graphic records with special qualities; X-ray, radar, and infrared photographs have proved extremely useful. However, the mechanics involved in obtaining photographic images frequently cause losing sight of the basic situation that brought these sensors into existence. Man's search for better graphic records produced photography, and any photograph, regardless of origin or the type of images displayed, is nothing more nor less than a graphic record; it records the intensity of energy received at the focal-plane. It is customary to think of the energy source as visible, or possibly infrared, light. If discussion is confined to this energy spectrum, most photographic interpreters will be on reasonably familiar ground.

Interpretation of photographic records of light intensity requires either a conscious or an unconscious consideration of several specific properties of the images contained in the photographs. Every photographic interpreter can name several properties of photographic images which he considers important, and some interpreters would include items which are not strictly characteristics of photographic images; spatial relationships are important, too. The author's list includes nine basic elements.

1. *Shape.* The shape of some objects is so distinctive that their images may be identified solely from this criterion. The Pentagon Building near Washington, D. C., is a classic example of the role of shape in interpretation.

2. *Size.* In many cases length, width, height, area, or volume are essential to accurate and complete interpretation. The volume of wood which could be cut from the stand in Figure 1 is dependent upon tree-size, stand density, and size (or area) of the stand.

3. *Tone.* Different objects reflect different amounts and wavelengths of light. These differences are recorded as tonal, or color, variations. The stand of mixed hardwoods shown in Figure 1 was photographed in late October at the peak of the fall color change. Species differences are obvious.

4. *Shadow.* Shadows can help or hinder the interpreter; shadows reveal invisible silhouettes but hide some detail. The shadows in Figure 2 provide information on the size and shape of this building which is not apparent

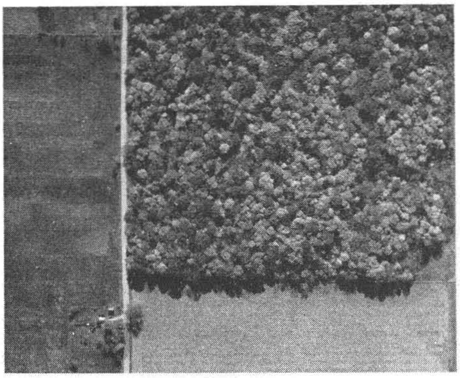

FIG. 1. Panchromatic-minus blue photograph of mixed hardwood stand at the peak of the fall color change. Lightest toned tree crowns are sugar maple; dark-toned crowns are generally oak. (University of Illinois photograph.)

from the image of the building alone. These same shadows obscure the detail in the lawn and sidewalk areas in front of the building.

5. *Pattern.* Pattern, or repetition, is characteristic of many man-made objects and of some natural features. The land-use pattern shown in Figure 3 is typical of areas of deep, wind-blown soils. Orchards and strip cropping are particularly conspicuous because of pattern.

6. *Texture.* The visual impression of roughness or smoothness created by some images is often a valuable clue in interpretation. Tree-size is often interpreted on the basis of apparent texture. Smooth, velvety textures are commonly associated with young saplings, while rougher, cobbled textures usually indicate older trees of sawtimber size.

7. *Site.* The location of objects with respect to terrain features or other objects is often helpful. The open pond and the flatness of the area of dark-toned vegetation in Figure 4

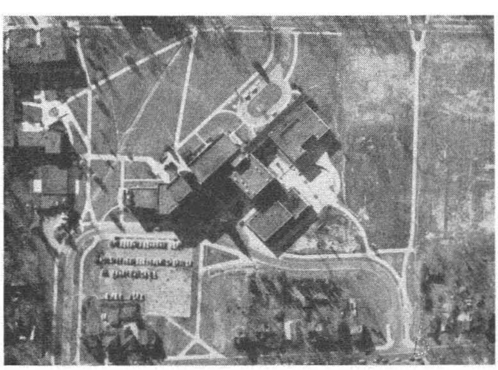

FIG. 2. The shadow of this building shows the steeple more clearly than does the image of the steeple itself. (University of Illinois photograph.)

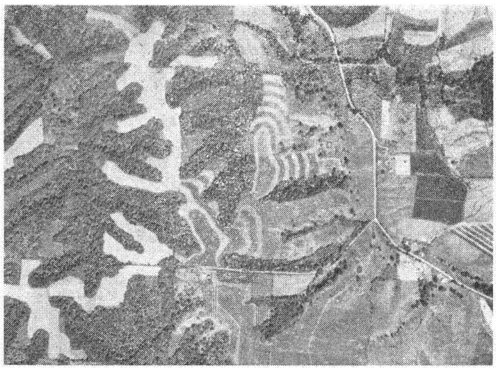

FIG. 3. Land-use pattern on loess in Calhoun County, Illinois. (U.S.D.A. photograph.)

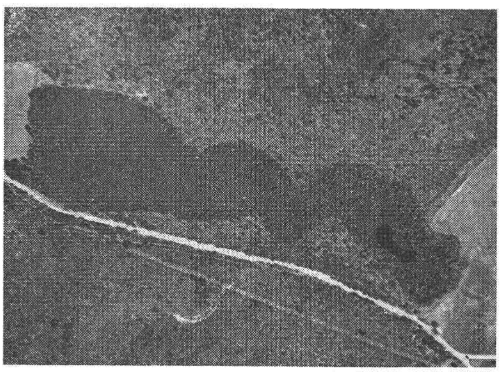

FIG. 4. Northern white cedar-balsam fir swamp in Leelanau County, Michigan. (University of Illinois photograph.)

both indicate a coniferous swamp. In this area of Michigan, northern white cedar and balsam fir are the two predominant swamp conifers. The stand shown here is actually a mixture of both species.

8. *Association.* Some objects are so commonly associated with other objects that one indicates or confirms the other. In Figure 5 the two tall smokestacks, large building, coal piles, conveyors, and cooling towers are obviously related. This combination and arrangement of features identifies the installation as a thermal power plant.

9. *Resolution.* Resolution depends on many things but it always places a practical limit on interpretation. Some objects are too small, or otherwise lacking, to form a distinct image on the photograph. The lake in Figure 6 shows some interesting tonal patterns, but the exact location of the shore-line is not visible along much of the boundary of the lake. The shoreline failed to resolve because of insufficient tonal contrast between adjacent land and water surfaces. Boundary contrast or edge gradient is a factor in resolution (1).

Notice that seven items on this list are qualities that man developed in his early drawings. The last three items are important to interpretation because they tend to integrate or set limits on the others. Conscious or unconscious consideration of one or more of these basic elements is involved in every photographic interpretation. Integration of several elements strengthens any interpretation and contributes to the "convergence of evidence" frame of mind so aptly described by Colwell (2). Association, in particular, is closely related to the "convergence of evidence" concept.

A list of important considerations in photographic interpretation, similar to that above, is familiar to most photographic interpreters. The ease with which these same basic elements of photographic interpretation can be applied successfully to radarscope and infrared photographs is not as widely recognized. Radar and infrared sensing systems have been developed largely to meet military require-

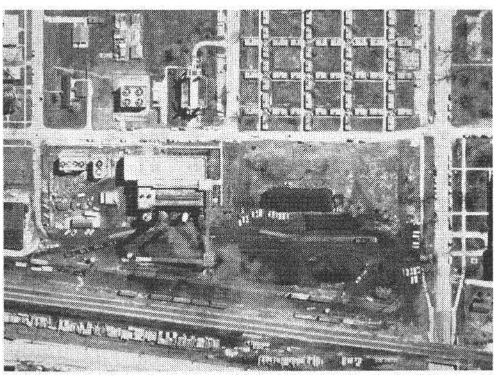

FIG. 5. Thermal power plant at the University of Illinois. (University of Illinois photograph.)

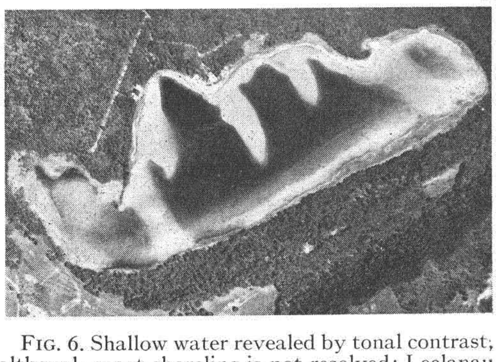

FIG. 6. Shallow water revealed by tonal contrast, although exact shoreline is not resolved; Leelanau County, Michigan. (University of Illinois photograph.)

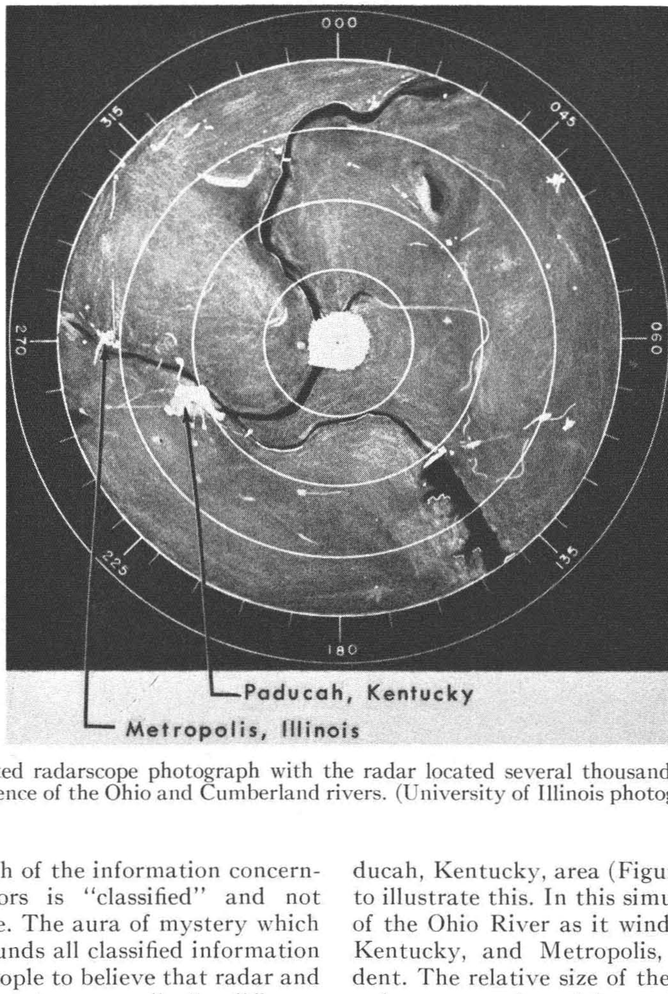

FIG. 7. Simulated radarscope photograph with the radar located several thousand feet above the confluence of the Ohio and Cumberland rivers. (University of Illinois photograph.)

ments, and much of the information concerning these sensors is "classified" and not readily available. The aura of mystery which popularly surrounds all classified information has led many people to believe that radar and infrared photography are radically different from visual photography and are the dirt scratchings of prehistoric man. Many people feel that it takes a "radar expert" or an "infrared expert" to interpret photography from these two classes of sensors. It is the author's considered opinion that this is not the case.

The development of orthochromatic, panchromatic, and infrared sensitive photographic films involved changes in spectral sensitivity, but these changes have been accepted as natural improvements of graphic recording techniques. Several forms of color photography have been accepted just as naturally. The development of radarscope and thermal photographic systems should be accepted in the same manner, since the change from one part of the energy spectrum to another influences the nature of the graphic records produced, but does not alter the basic elements considered in interpreting them. A simulated radarscope photograph of the Paducah, Kentucky, area (Figure 7) can be used to illustrate this. In this simulation the shape of the Ohio River as it winds past Paducah, Kentucky, and Metropolis, Illinois, is evident. The relative size of the bright spots, or radar returns, from Metropolis and Paducah suggests that Paducah is several times the size of Metropolis. Population figures confirm this, for Paducah numbers over 40,000 persons, while Metropolis claims less than 10,000 persons.

Both the shape and size of the dark, or "no-show," area at the southeast edge of the simulation agree nicely with the general map outline of Kentucky Lake. This lake and the Ohio River can be identified because of tonal contrast. The radar returns from the land areas bordering these bodies of water provide the distinct land-water contrast characteristic of many radarscope photographs. Another area of distinct tonal contrast can be seen approximately 12 miles northeast of the radar. A lake might produce this appearance, but there is no lake at this location. This tonal contrast represents an abrupt change in ground elevation, where an area of rolling hills gives way to the low flood plain of a trib-

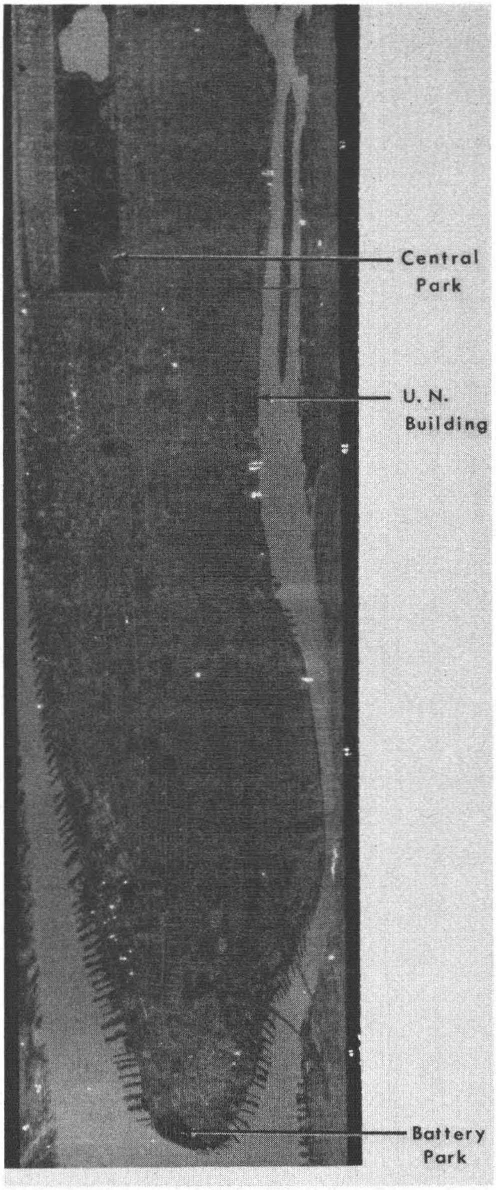

FIG. 8. Infrared (thermal) photograph of Manhattan Island. (Photograph by HRB-Singer, Inc., for the U. S. Air Force.)

utary of the Ohio River. Here the no-show area results from lack of illumination of the ground at the base of the hills. In other words, the no-show area is in the shadow of the hills. Radar shadows are common and quite significant in mountainous areas.

Pattern is seen in the radar returns from highways and railroads in several parts of the simulation. The roads themselves seldom produce a visible return, but the buildings, bridges, embankments, and vehicles on the roads produce patterns of returns that form linear traces along the transportation routes. Many man-made features produce distinct radar return patterns as do the parallel ridges of the Appalachian and several other mountain chains.

Texture is present in radarscope presentations, but it is particularly difficult to simulate. Texture is produced by roughness of land surfaces, by waves on water, and by other features with irregular or interrupted surfaces.

Site is important in interpreting radar returns from many features, and the shadow area noted earlier is a good example. Interpretation of radar returns from bridges and dams involves site considerations, as radar returns in the no-show areas caused by bodies of water are not apt to be houses or cities. In Figure 7 returns from bridges or dams appear at seven points. The bright linear return at the near edge of Kentucky Lake represents Kentucky Dam. Lakes and dams of this size usually have power plants associated with them, and Kentucky Lake is no exception. The power plant can be seen as the small, blockish return at the east end of the dam, clearly indicating that associations between several features are important in radarscope photo interpretation.

The fact that the radar return from the Kentucky Dam power plant merges with the return from the dam is a function of two things: First, the distance between the dam and power plant; and second, the resolution potential of the radar. The lack of a distinct no-show area from the surface of the Cumberland River is another example of resolution effects. Note that the trace of the Cumberland River is frequently shown by radar returns from the far bank even where the no-show area of the water surface fails to resolve.

Although this simulation was prepared specifically for this paper and represents no particular radar system, it does have many of the characteristics of long pulse-length, wide beam-width radars. Short pulse-length and narrow beam-width radar systems are in existence and produce radarscope presentations remarkedly similar to some visual aerial photography.

A graphic record of infrared radiations from Manhattan Island obtained at 11 p.m. on January 9, 1958 is reproduced in Figure 8. This record was produced by HRB-Singer, Inc., Science Park, Pennsylvania, for the U. S. Air Force and was obtained with an infrared or thermal, sensing system. If this graphic record is considered in terms of shape, size, tone, shadow, pattern, texture, site, association, and resolution, the interpretation of many infrared images becomes quite simple.

The shape, size, and tone of the dark area at the south end of Manhattan Island permit locating Battery Park. The Brooklyn and Manhattan bridges connecting Manhattan with Long Island are clearly visible due to tonal contrast. Size, shape, pattern, site, and association all have some bearing on this interpretation. A minor amount of map comparison would supply enough information on pattern and association to permit interpretation of the images representing City Hall, China Town, and Canal Street approach to the Holland tunnel. Farther north Central Park provides a distinctive pattern. Central Park and Broadway Avenue provide sufficient association to identify the bright images from the Times Square area. The dark area representing the United Nations Headquarters is also apparent.

Throughout this paper the principles that make radar and far infrared sensing systems work have been completely ignored. Despite this it has been possible to demonstrate a certain degree of interpretive success with both sensors through the application of nine basic elements found to be important in interpreting visual photographs. When these nine elements are coupled to a basic understanding of a sensing system and its graphic records, interpretations can be greatly improved. However, such improvements result, primarily, from a better understanding of what causes the graphic record to show shape, size, tone, shadow, pattern, and texture. Integration of these characteristics with site, association, and resolution considerations significantly strengthens interpretation. Regardless of how, or where, interpretation begins, conscious or unconscious consideration of these nine basic elements is essential to effective interpretation of graphic records from many sensing systems. These nine basic elements—shape, size, tone, shadow, pattern, texture, site, association, and resolution—are elements of photographic interpretation common to several sensors.

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