selected with considerable freedom so as to minimize the sunspot effect.

REFERENCES

[1] Tewinkel, G. C., "Kelsh Plotter Notes," PHOTOGRAMMETRIC ENGINEERING, v. XXVII, n. 5, p. 485, 1961.

[2] Sverdrup, H. U.; Johnson, Martin W.; Fleming, Richard H.; "The Oceans, Their Physics, Chemistry and General Biology," Prentice-Hall, 1961; page 70.

[3] Bigelow, Henry B., and Edmonston, W. T., "Wind Waves at Sea Breakers and Surf," U. S. Navy Hydrographic Office Publication No. 602, 1947 (1953).

[4] Sverdrup, *ibid.*, page 528.

*Photographic Interpretation Keys—A Reappraisal**

GEORGE F. BIGELOW,†

U. S. Army Personnel Research Office, Washington 25, D. C.

INTRODUCTION

THOSE present at the Annual Meeting of the Society in 1955 will recall that the subject of photographic interpretation keys was not only the main topic of a panel, but was also the subject of a lively symposium. At that time, the various aspects of such keys —their concept, format, content and methods of production—held an extremely high priority. This was the apex of a period of burgeoning enthusiasm for photographic interpretation keys, that lasted for perhaps a decade, beginning in 1948.

Looking back to 1948, the concept of keys can be compared with that of a newborn baby, openly admired and cosseted, but never disparaged directly, even when secretly regarded as a moronic homunculus, incapable of useful action. In 1963, this baby has developed into a gangling, fifteen-year-old boy —frequently blasted for his mistakes, seldom praised for anything he does well—but actually performing many useful functions—shoveling snow, for example, or putting chains on his father's car.

Of late, there is a growing tendency among photo interpreters and design engineers to deprecate the need for, and value of, keys. This critical opinion has been expressed so often, that it seems time to examine the purpose, history, general trends and future directions of photo interpretation keys; to find out what has actually happened to this once-flourishing field, and whether hope exists that the program will survive the critics' barrage and attain useful maturity. In doing this, some specific charges against keys will be discussed, and some possible solutions developed which may enhance the effectiveness of future keys.

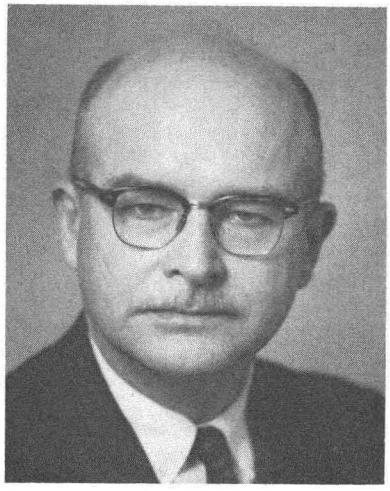
TERMINOLOGY

In the broadest sense, any interpreted and annotated (or captioned) photograph is a key —thus, a Matthew Brady photograph of General Grant, carefully studied, could have permitted later recognition of that controversial figure by one who had never seen him before. For the purposes of this paper, the definition found in the interservice Photographic Interpretation Handbook (1954) and similar to that in the MANUAL OF PHOTOGRAPHIC INTERPRETATION (1960) will obtain: "Reference material designed to facilitate rapid and accurate identification and determination of significance of objects by the photo interpreter." Note that this definition is intrinsically a broad one; it does not insist that a key be a bound volume, or even that it include graphics. The term thus admits the specialized techniques of disk, punch-card and essay keys, as well as the more common dichotomous and integrated-selective types. Furthermore, it encompasses the various

* Paper presented at the 29th Annual Meeting of the American Society of Photogrammetry, Washington, D. C., March 25–28, 1963.

† The opinions expressed in this paper are those of the author and do not necessarily reflect official Department of the Army policy.

EDITOR'S NOTE: The Abstract for this paper is on page 482 of the 1963 YEARBOOK.



GEORGE F. BIGELOW

keying principles of regional, subject, item, and analogous area keys; technical and nontechnical; and other subcategories originally defined in the report of Commission VII in 1952. It is equally applicable to reference components of automatic data processing systems, which will involve high speed retrieval and display of key materials.

Although the actual term "key" saw no common use by photo interpreters prior to 1946, there were many interpretation references produced in World War II and earlier, and even one or two Army studies from World War I, which are properly regarded as being keys. The author recalls contributing in 1943 to the preparation of the now obsolete Navy reference material on Japanese antiaircraft positions.

An attempt to trace the early use of the word "key" indicates that Colwell's work in 1946 on tropical vegetation types is among the earliest to incorporate it. The term, drawn from the taxonomy of botany and geology, apparently combines Webster's 9th meaning —"a table in which the salient characteristics of a group of photos or animals (or of species, genera, etc.) are arranged so as to facilitate the determination of their names and taxonomic relationships"—with his 5th: "that which serves to reveal, discover or solve something."

When describing the then new approach at the 1948 Symposium in Military Interpretation, Colwell stated: "as in taxonomic botany or zoology, salient aids to identification can be set forth in a key to the population being classified." And although these taxonomic keys take the form of word descriptions, he has made it clear that whenever possible, in a key for the photo interpreter, verbal descriptions should be combined with excellent photographic examples. Roscoe (1955) and others have also stressed this basic need for good illustrations.

Today, nearly all keys in current use are copiously illustrated with vertical photographs, supplemented with obliques; hence the interpreter almost never has to base his conclusions solely on a textual description. O'Neill (1953) has stressed the importance of ground familiarization with various types of objects prior to actual photo interpretation. For example, he should have first-hand knowledge of a birch tree's appearance before he attempts to pick one out on an aerial photo. However, as a military interpreter is usually confronted with items and areas of interest where ground familiarization is impossible, many keys have partially overcome this difficulty by using terrestrial photos of adequate scale and detail.

In this paper, the term "photo interpretation keys" is equivalent to the more general term "image interpretation keys," coined to admit imagery produced by such newer sensors as infrared and side-looking radar.

DEVELOPMENT OF THE KEYS PRODUCTION PROGRAM

A brief review of the history of keys shows that military necessity undoubtedly spurred the development of the large family of interpretation aids originating in World War II. Products of this early period vary widely both in form and in content, reflecting the relative novelty of this type of presentation. Subject matter was of immediate vital concern to the interpreter supporting troops overseas in the European or Japanese theater, therefore speed of production was a prime consideration; such urgency notwithstanding, some early keys, e.g., certain Photo Industrial Studies, contained sufficiently valuable and complete information that they are still used for basic reference. Time and changing requirements have removed others to the archives, like old soldiers retired from active service.

Immediately following the war the Navy published a few more military keys, incorporating useful material and techniques developed late in the war; for example, a bomb-damage assessment key incorporated results of postwar ground surveys by the U. S. Strategic Bombing Survey. The Interim

Photo Interpretation Handbook of 1947 contained sections on industrial and beach analysis which are, in effect, keys. The same revision dropped sections on Japanese electronics, aircraft, guns, etc., as no longer applicable to the Navy's needs.

As interest in purely military subjects declined, emphasis on photo interpretation in general shifted from cultural to natural features; this change of interest was reflected in the subject matter of numerous keys produced by university research groups from 1947 until 1954. Some of these contributing universities and their specialties were: Purdue (vegetation; soils; trafficability); Catholic University (vegetation species; terrain analysis); Cornell (ground conditions; beaches); Kansas University (analogous desert area); Northwestern University (glacial landforms; farm crops; irrigation structures); the University of Oklahoma (marsh and swampland areas); and the University of Maryland (Antarctic surface features). Actually, these university keys were preceded by earlier approaches to terrain analysis; the U. S. Geological Survey had already published engineering notes relating to natural features during the war, and the Navy manual on Pacific Landforms and Vegetation (1945) is a fairly comprehensive early key to these features.

Postwar interest was by no means restricted to the university groups. In 1948 Moessner recommended the use of keys for photographic interpretation training in forestry, and stated that such keys had already been found effective by the U. S. Forest Service. Hittle (1949) developed tables for landform and materials classification, relating them to aerial photographs. Seely (1949) devised forestry keys to aid in species identification. Keying of landforms as a growing technique was addressed by Waldo and Ireland (1955) and Heath (1956). Pownall (1950) and Witenstein (1952; 1954) related keys to urban land-use problems; Colwell (1948), and Simontacchi, Choate and Bernstein (1955) discussed approaches to vegetation keys; lively interest in the Antarctic caused Sager (1951), Roscoe (1953) and others to develop keys to glaciated and perma-frost areas; Truesdell (1950) expressed the Navy's need for coastal terrain and beach trafficability studies, and in 1954 Tator related drainage patterns to structure; in short, the construction of keys to landforms and vegetation, and the technology of such keying, occupied many specialists over a number of years, and the effort continues even today.

Meanwhile, the lull in military keys construction was short-lived as the outbreak of war in Korea redirected attention to target areas, and the need for up-to-date keys. Commission VII was formed in 1951 to investigate major unsolved problems in photo interpretation and to suggest approaches to their solution. The Interservice Committee on Photographic Interpretation Research, Keys and Techniques developed complete definitions, that are still in use for all types of keys, and the Air Force threw its weight into a concentrated keys production program which lasted from about 1952 until very recently, and resulted in a number of excellent keys both to military subjects and to geographic areas. The former U. S. Forest Service Photo Interpretation Keys Project, where the author spent four years, was probably the major single contributor to the Air Force program. At the same time, a number of private companies produced military keys under Government contract; prominent among them were Broadview Research Corporation; Aero Service Corporation; and Photogrammetry, Incorporated.

Meanwhile the Navy again expanded its keys production effort, and in 1958, realizing the need for more keys of a specifically tactical nature (in addition to their extensive tactical manual published in 1954), the Army again entered the field of keys production.

From about 1950 to 1958 interservice and private interest in techniques of keys and keying grew intense, as evidenced by various ASP panels and symposia, where specialized applications were discussed, such as associative keys (Roscoe, 1953; Heath, 1955 and 1957; and Landis, 1955); industrial keys (Maynard, 1955; Chisnell and Cole, 1958 and the author, 1955); and mechanical approaches e.g., punch-card keys (Weiner, 1955). The peak of general interest was probably reached in 1955.

In 1957, however, Cheney's survey of techniques used in photographic interpretation schools found that 78% of the geology departments contacted were not using keys in their training programs. He infers that their courses would be greatly improved by such use. A survey by Broadview Research Corporation (DeLancie, et al., 1957) compared the merits of integrated-selective with dichotomous military photographic interpreta-

tion keys, and found them both of equal value—and especially useful for training inexperienced men. The need for good keys organization was also pointed up in this study. In the same year Lewis emphasized the value of analogous keys in dealing with normally inaccessible geographic areas.

Military keys produced during this period were normally published as interservice manuals, for use by two or more of the Armed Forces. Joint discussions were held to ensure the value of new production, and to avoid overlapping effort. The Air Force produced its greatest number of keys in 1959, reflecting the usual lag caused by production. When making a conventional key, steps involved ordinarily include planning, photo and literature search, compilation (selection, analysis, writing, editing, rough page mock-up, evaluation, final layout), printing, publication and dissemination. All of these steps are time-consuming.

At present, the military keys program, although reduced, still continues, with both the Army and Navy actively participating. Besides new keys production, a number of earlier manuals have been revised or updated to incorporate new or better materials. In addition, keys are produced from time to time by interpreters in other professions. Such production has not been limited to the United States. In forestry, for example, Sayn-Witgenstein of the Canadian Department of Forestry published a key to recognition of tree species from their crown characteristics in 1960, and in Mexico, the Mexican Forest Research Office is currently developing keys to aid in their national forest inventory. New techniques are also being applied here and abroad. Doverspike and Heller's paper presented at Delft in 1962 considers the identification of tree species from color photography. From these, and other examples, it is evident that keys production is still a "going concern" rather than a lost art.

Purpose

Some critics of photographic interpretation keys may have lost sight of the original purpose for which they were designed. Primarily keys serve three purposes: First, as a training aid for the new student; second, as indoctrination into new areas or items for trained personnel, and third, as a comprehensive library reference for the experienced interpreter. The world of photo interpretation is limited only by the camera's ability to disclose its myriad discrete images; therefore, no one instructor, or even an entire staff, can be fully cognizant of all the areas and objects of interest, with their many variations, that should be taught. For training purposes the instructor needs photo records of a great many more objects and areas than he will ever attempt to memorize. As a training aid, it is hard to imagine any acceptable substitute for well-prepared keys that would permit the student to widen his classroom-gained experience so rapidly. Given enough keys, there are virtually no limits to the extent of his supplementary self training.

An experienced military interpreter reassigned to a new geographic area, or redirected into a new subject of specialization, will draw on appropriate keys even more heavily; being regarded as already trained, he may receive little additional indoctrination. Whitmore praised military keys in 1953, describing them as making not only a major contribution to identification, but also to evaluation of significance; they are a means by which information gathered by an expert can be passed readily to some one who is far from expert in a particular field. Certainly a memory association will often increase an interpreter's ability for deductive reasoning, and here the third basic function applies—the use of keys for reference. If an interpreter sees a half-forgotten industrial type, for example, its image may remind him of a similar plant seen in a key some years earlier; reviewing the appropriate volume will greatly expedite his decision. Thus, the interpreter's situation is comparable with that of a practicing attorney, who refers to a comprehensive law library to refresh his memory; similarly, few writers or English professors completely dispense with their unabridged dictionaries and encyclopedias, even though they need not resort to them on a regular basis. Therefore, as imagery is often viewed that calls for confirmation through comparison with known photo examples the photo interpreter should obviously have his own technical library of such examples. Existence of any key is justified if it can occasionally supply the missing piece that completes an important puzzle.

No interpreter is an expert in every subject. As Whitmore also pointed out, there is no such thing as a fully qualified photo interpreter; however, a man may be considered as well qualified in his field of specialization; therefore, a military interpreter concentrating

on airfield electronics may be completely unfamiliar with atomic energy installations; when asked to identify one, his first recourse is necessarily to the appropriate key.

Certainly, keys should never be regarded as the interpreter's only reference. Coleman (1952) recognized that in a good reference system, keys are combined with various charts, diagrams, graphs and other aids to analysis.

Neither should keys be considered substitutes for photo interpretation. What the interpreter sees on a photograph is often only a clue to far more significant information; identification of such a clue is merely the first step in his reasoning. A simple and effective example of such a clue is given by Babington-Smith (1957): A rubber ball that bounces into the street in front of a motorist; although he sees nothing else, the driver instinctively applies his brakes, expecting a child to follow the ball. Unless a military interpreter is thoroughly conversant with the pertinent intelligence regarding his area of concern, he may be flying blind, i.e., perceiving the right clues, but having nothing tangible to relate them to, his chances of reaching the right conclusion as to significance are greatly reduced. As Seymour (1957) points out, military keys are useful aids; they are not the final guide to significance.

In short, as Frost (1952) puts it, "a photo interpretation key serves to *aid* in identification of objects and analysis of patterns; it does not interpret." Therefore, in order to utilize keys efficiently, the analyst must recognize that keys have their limitations; the user is limited to varying degrees by the completeness of the key, the background of those who make it, and his own background, powers of observation and analytical ability.

Scope

Keeping the purpose of keys in mind, the user must next be considered. The scope of photographic interpretation keys is indeed wide, embracing nearly all fields in which photo interpretation is used. In addition to military science, keys have been found applicable to such disciplines as geology, geography, soils science, forestry and engineering. Keying techniques can be used to solve special problems in archaeology, beach trafficability, and urban area analysis. They are sometimes used as an aid in mapping (Hedden, 1958). By now, many pertinent military and non-military subjects have been at least partially presented in keys, some separately, others combined in the various regional keys to given geographic areas. Lists of military keys also include related material on primarily photogrammetric subjects such as underwater depth determination, height determination from shadows, and estimation of the speed of moving vessels.

Basic Problems and Recommendations

In order to ascertain realistically the current and future value of keys, some of their alleged failings must be examined. Admittedly, certain keys justify one or more of these criticisms. However, when it is recognized that more than two hundred keys have been produced, not including countless individual "desk file" keys, the danger becomes apparent of judging the whole "ball of wax" on the basis of a casual acquaintance with three or four of the less effective older manuals. A recently completed study of more than fifty military photographic interpretation keys, and a cursory examination of many more, leads the author to believe that any blanket criticism is akin to condemning all photogrammetry reference materials because a few are badly organized or contain ineffective illustrations. The selective user will find useful material available in many subject areas, and if certain recommended changes and improvements are made, most of the library should become very valuable.

Keys are sometimes regarded as too bulky; as containing obsolete material; as being poorly organized and hard to use; as containing poor-quality illustrations; a final criticism is that keys seldom provide the interpreter with a complete answer to his problems.

These charges will be considered in order—the first concerns their bulk: To be sure, there are several multi-volume keys. One military key, published in World War II, comprised ten volumes. However, each volume was actually a self-contained subject key. Nearly all military keys in common use today are single-volume manuals; a few have two volumes, but it is believed that none recently published has more than two, as an effort has been made to consolidate the largest editions into fewer volumes. Colonel Hauser said in 1960 that it would take a truck and trailer to carry a copy of every photographic interpretation key developed; fortunately, the military man operating in a given area needs only a small fraction of the total store. A single regional key to the theater concerned, augmented by pertinent subject material, should suffice.

In the foreseeable future, many military interpreters will be integrated in automated systems for image information processing, of the type described by Mumbower and Richards (1962). Automated data storage and retrieval will be an integral part of such systems. Applicable keys material, together with maps, charts and other intelligence references, will be miniaturized and stored within the reference component, using a system similar to that described by Laurent (1962), whence it will be retrieved by use of a suitable code, and projected for direct viewing and comparison with the imagery being scanned. Obviously, preparing the reference store for such an advanced system will entail a massive initial effort of recompiling and updating existing material. When bound volumes are eliminated, so will be the concept of consecutive pages; each slide, or film "chip," will have to stand alone—there should be no dangling ends of continuing text leading to previous or subsequent slides. The vast store capacity of a computerized system would far exceed the demand for material in a given geographical area. Required references would be drawn from an extensive central store to meet user demands, and the problem of bulk in the field would be resolved.

The same problem appears of far less concern to the non-military specialist such as the geographer, forester or civil engineer, who may never have an automated system, but presumably can find adequate shelf space and viewing room. Here again, the area of immediate specialization ordinarily limits the number of keys required, e.g., a forester working in the northwestern United States can dispense for the time being with keys to vegetation in other parts of the world.

In a training situation, an extensive library of keys may become necessary, but presumably most schools have expandable library shelf space, so here the problem of bulk appears of far less consequence. Miniaturization could well be applied to civilian use also. The new family of teaching machines seems well adapted to displaying keys material from a reduced format. Using programmed learning techniques, a class of twenty students could simultaneously view and discuss a given photo example, and though miniaturization, a number of views could be incorporated on each small slide.

Obsolescence, the second criticism, applies primarily to military keys. Obviously, the characteristic appearance of many landforms and vegetation species does not require frequent updating. Subject keys to certain military items, on the other hand, do become obsolete—sometimes very suddenly—as did those on Japanese World War II equipment. Once this problem is recognized, the need is stressed for updating basic references. More characteristically, there is a gradual turnover in the life cycle of military equipment, as new types are designed, tested, developed, produced and at last gradually replace the older models. This life cycle also applies, but over a longer time, to large cultural items such as urban areas, industries, airfields, port facilities, and electrical power plants, and correlates directly to the concept of activity keys. The cycle for an airfield ranges from original site selection and clearing through various construction phases; years of active, use, repair, and maintenance; to final abandonment, deterioration, and perhaps return to an orginal agricultural function. If good examples of such activity cycles are developed and illustrated, the value of keys should be greatly enhanced.

When automated systems are in common use, the problem of obsolescence can be handled by a continuous maintenance program. A service organization would regularly review the materials in the central reference store, purge the files of obsolete items, and replace them with up-to-date material. Supplemental examples for inclusion would be furnished by interpreters in the field, even as today. Individual desk files of interesting new imagery should be maintained, and any items of unique interest forwarded to the cognizant reproduction facility for inclusion in the central store. Under time pressure, the titling information of an exposure showing an unfamiliar item should be forwarded for further analysis and possible inclusion in the system.

Admittedly, some keys in their present form are difficult to use; this is often the result of conventional binding methods which create a page hump, hindering the use of the stereoscope. Many recent keys are combbound, and a few have ring bindings. Assuming a time frame of several years before most interpreters actually have available a completely automated system, it is suggested that as a part of the immediate updating program, and prior to miniaturization, all currently valuable keys be adapted to the ring-type binder, permitting easy updating and addition of supplementary material. The ring binder permits a large number of papers to lie flat, and unlike the comb binder, does

not require a special device for rapid opening and closing.

In another sense, difficulty of use stems from faulty organization. Some keys are merely "picture books"; others lack proper glossaries and photo indexes. If each key is organized to meet the specific needs of the user, difficulty of use should be largely overcome, as indeed it has been, in the better organized manuals: The importance of good organization cannot be overemphasized. In 1955, this was stressed in separate papers by Colwell, Roscoe, and Simontacchi (et al.). Waldo and Ireland (also in 1955) list the following organization considerations: (1) purpose and level of keys; (2) choice of the key to be used, and (3) thorough analysis of the available background material. Ideally, the photo illustrations should include both small and large scale verticals, selected obliques and ground photos, supplemented with maps and other material. To this basic list should be added comparative cover (recommended by Dill, 1959); good examples of the activity cycle whenever applicable; color photography (McDaniel and Arntz, 1959); and when available and pertinent, the comparative records of other sensors. Hoffman (1960) has stressed the need for radar keys; the supplementary value of both radar and infrared imagery, using the convergence of evidence technique, was recently stated by Van Lopik (1962). Assuming that the chief value of radar and infrared in interpretation is to supplement data from conventional aerial photographs, certain selected material should be included in existing and new keys to insure a fuller understanding of this relatively unfamiliar imagery.

The principle that organization must meet the needs of the user is reaffirmed by some apparently divergent opinions. Such authorities as Belcher (1948), and McLerran (1957), imply that keys are designed by experts for other experts, and therefore the user should be an experienced man with a solid background in his field of specialization. Others, like Schatzley (1954); Chisnell and Cole (1958) and DeLancie, et al. (1947) indicate that if a key is organized logically, it can be used rapidly and effectively by those with relatively little subject experience.

This apparent divergence in opinion is clarified if it is appreciated that those who insist on expert background are discussing specialized keys, e.g, to soil conditions, a subject requiring an engineer's knowledge of the variety of possible subsurface conditions and their relation to subsurface patterns, whereas the exponents of keys for inexperienced men are speaking of military training aids designed to permit rapid recognition of relatively standardized items, such as guns or warships, by students previously unfamiliar with their appearance from the air. Such references, as Schatzley points out, must augment the individual's background, and not confuse him.

Unlike those designed for the soils specialist, military subject keys should be oriented toward the average individual, recognizing the widely diverse backgrounds inherent in any large group of military students. The criticism of illustration quality is admittedly justified when applied to many early keys. Photolithographic and other methods used for mass reproduction caused considerable loss of detail. This sometimes was painfully evident in the wording of captions, which might state: "on the original photos three soldiers are entering a van"; hedging like this was intentional, when the analyst was reasonably certain that important small details would be lost in final printing.

Fortunately, recent refinements in the 300 line screen technique have resulted in illustrations which, even when produced in sizeable numbers, retain an estimated 95 per cent or more of the original detail. When dealing with extremely small tactical material, still higher reproduction fidelity is obtained by continuous-tone photocopy; this method has been used very successfully by the Army. However, the relatively high cost of this method (approximately ten times that of photolithography) has prohibited its general use for large keys requiring wide dissemination. In many instances, limited photocopy editions have supplemented the lithographic versions.

Obviously, in adapting keys for use in automatic data processing systems, miniaturization and rear view projection introduce their own reproduction problems; however, the extremely high resolution inherent in certain new films should help to reduce loss of image detail in miniaturization. Research now in progress is attacking this problem area.

Finally, in answer to the criticism that keys seldom provide the complete answer, the basic purposes of keys are again stressed: They are training aids, indoctrination material, and working references. They are not designed to be a substitute for the reasoning

ability of the qualified photo interpreter. Each problem must be weighed in the light of its own evidence, and a decision made. The degree to which any key helps the human to decide will vary with the complexity of the problem, and the number of different variables involved.

A Forward Look

During this investigation, interviews with supervisory personnel supported the author's opinion that keys are still used frequently by many military and civilian interpreters. However, our rapidly advancing technology admits no room for complacent satisfaction with the keys library in its present form. Public acknowledgement of the military photo interpreter's role in the Cuban crisis has served to focus much general interest on a relatively unknown profession, and to enhance its prestige. If interpreters are to receive the full support that is now considered justified, both in the light of their recent contributions and the possibility of potential new emergencies, it is strongly recommended that the keys production and maintenance program be kept active and current; that it be expanded to incorporate a comprehensive range of imagery from the new sensors and platforms, and made fully compatible with the reference and training requirements of the future, especially those related to automatic data processing systems.

If such a program is actively pursued and the original purposes are kept in mind, keys should continue to be the photo interpreter's primary reference and training aid for many years to come.

Selected Bibliography

1945. U. S. Naval Photographic Interpretation Center, "Pacific Landforms and Vegetation." OPNAV 16-UP107 reprinted 1950 as PIC Report 7, NAVAER 10-35-560.

1946. Colwell, R. N., "The Estimation of Ground Conditions from Aerial Interpretation of Vegetation Types." Photogrammetric Engineering, Vol. XII, No. 2, p. 159.

1947. Sisam, J. W. B., "The Use of Aerial Survey in Forestry and Agriculture." Oxford, Imperial Forestry Bureau, 59 pp.

1948. Belcher, D. J., "Determination of Soil Conditions from Aerial Photographs." Photogrammetric Engineering, Vol. XIV, No. 4, pp. 482–488.

Colwell, R. N., "Aerial Photographic Interpretation of Vegetation for Military Purposes." Photogrammetric Engineering, Vol. XIV, No. 4, pp. 472–481.

Moessner, K. E., "Forest Stand Size-Class Keys for Photo Interpreters." *Journal of Forestry*, Vol. XLVI, February 1948, pp. 107–109.

1949. Hittle, J. E., "Airphoto Interpretation of Engineering Sites and Materials." Photogrammetric Engineering, Vol. XV, No. 4, pp. 589–602.

Seely, H. E., "Air Photography and Its Application to Forestry." reprinted in Photogrammetric Engineering, Vol. XV, No. 4, pp. 548–553.

1950. Pownall, L. L., "Aerial Photographic Interpretation of Urban Land use in Madison, Wisconsin." Photogrammetric Engineering, Vol. XVI, No. 3, pp. 414–426.

Truesdell, P., "Naval Interest in Photogeology." Photogrammetric Engineering, Vol. XVI, No. 3, pp. 431–433.

1951. Kohn, C. F., "Aerial Photographs in Geological Analysis of Rural Settlements." Photogrammetric Engineering, Vol. XVII, pp. 759–771.

1951. Powers, W. E., "A Key for the Photo Identification of Glacial Landforms." Photogrammetric Engineering, Vol. XVII, No. 5, pp. 776–779.

Sager, R. C., "Aerial Analysis of Permanently Frozen Ground." Photogrammetric Engineering, Vol. XVII, No. 4, pp. 551–571.

Tator, B. A., "Some Applications of Aerial Photographs to Geographic Studies in the Gulf Coast Region." Photogrammetric Engineering, Vol. XVII, No. 5, pp. 716–725.

1952. American Society of Photogrammetry, "Manual of Photogrammetry." 1952 Edition, Chapter XII, pp. 553–558.

Coleman, C. G., Jr., "Naval Photographic Interpretation." Photogrammetric Engineering, Vol. XVIII, No. 3, pp. 486–489.

Colwell, R. N., Bradshaw, K. E., Smith, H. T. U., Thoren, R., Von Drabbe, C. A. J., "Report of Commission VII (Photographic Interpretation) to the International Society of Photogrammetry." Photogrammetric Engineering, Vol. XVIII, No. 3, pp. 375–451.

Frost, R. E., "Discussion of Photo Recognition, Analysis, and Interpretation and Photo Keys." Photogrammetric Engineering, Vol. XVIII, No. 3, pp. 502–505.

Roscoe, J. H., "Contribution to the Study of Antarctic Surface Features by Photogeographical Methods." Thesis—Maryland University, 6 Volumes.

Witenstein, M. M., "The Application of Photo Interpretation to Urban Area Analysis." Photogrammetric Engineering, Vol. XVIII, No. 3, pp. 490–492.

1953. O'Neill, H. T., "Keys for Interpreting Vegetation from Air Photographs." Photogrammetric Engineering, Vol. XIX, No. 3, pp. 422–424.

Rabben, E. L., "Close Support Photo Intelligence for Ground Forces." Photogrammetric Engineering, Vol. XIX, No. 1, pp. 144–150.

Roscoe, J. H., "Antarctica." AFM 200-30, Department of the Air Force 17 pp.

1953. Roscoe, J. H., "Photogeography." *in*—Comm. on Geophysics and Geography, Research and Development Board, Washington, D. C. "Selected Papers on Photogeology and Photo Interpretation." April, 1953, pp. 55–102.

Whitmore, F. C., Jr., "The Dilemma of Military Photo Interpretation." PHOTOGRAMMETRIC ENGINEERING, Vol. XIX, No. 3, pp. 425–427.

1954. Hoffmann, P. R., "Interpretation of Radar Scope Photographs." PHOTOGRAMMETRIC ENGINEERING, Vol. XX, No. 3, pp. 406–411.

Department of the Army, Navy, and Air Force "Photographic Interpretation Handbook," TM 30-245, NAVAER 10-35-610, AFM 200-50, April 1954, Section IV, Photo-Interpretation Keys, pp. 100–109.

Schatzley, B. L., and Karably, L. S., "An Introduction to Photo Interpretation Problems and Research." PHOTOGRAMMETRIC ENGINEERING, Vol. XX, No. 3, pp. 428–443.

Summerson, C. H., "A Philosophy for Photo Interpreters." PHOTOGRAMMETRIC ENGINEERING, Vol. XX, No. 3, pp. 396–397.

Tator, B. A., "Drainage Anomalies in Central Plains Regions." PHOTOGRAMMETRIC ENGINEERING, Vol. XX, No. 3, pp. 412–417.

Witenstein, M. W., "Photo Sociometrics —The Application of Aerial Photography to Urban Administration and Planning Problems." PHOTOGRAMMETRIC ENGINEERING, Vol. XX, No. 3, pp. 419–427.

1955. Bigelow, G. F., "A Preferred Approach to the Military Photo Interpretation of Industries." PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 5, pp. 579–582.

Black, L. D., "Regional Keys are Valid Geographical Generalizations." PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 5, pp. 706–708.

Colwell, R. N., "The Photo Interpretation Picture in 1955." PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 5, pp. 720–724.

Heath, G. R., "An Associative Method of Regional Photo Interpretation." PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 5, pp. 589–598.

1955. Landis, G., "Concept of Validity of Association Photographic Interpretation Keys in Regional Analysis." PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 5, pp. 705–706.

Maynard, P., "Validity of Photo Interpretation Keys in the Interpretation of Industry." PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 5, pp. 714–716.

Roscoe, J. H., "Introduction of Photo Interpretation Keys." PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 5, pp. 703–704.

Simontacchi, A., Choate, G. A., Bernstein, D. A., "Considerations in the Preparation of Keys to National Vegetation." PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 5, pp. 582–588.

Waldo, C. E., and Ireland, R. P., "Construction of Landform Keys." PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 5, pp. 603–609.

Weiner, H., "The Mechanical Aspect of Photo Interpretation Keys." PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 5, pp. 708–711.

1956. Gwyer, J. A., and Waldron, V. G., "Photo Interpretation Techniques, A Bibliography." U. S. Library of Congress, Technical Information Division, Washington, D. C.

Heath, G. R., "A Comparison of Two Basic Theories of Land Classification and their Adaptibility to Regional Photo Interpretation Key Techniques." PHOTOGRAMMETRIC ENGINEERING, Vol. XXII, No. 1, pp. 144–168.

McNeil, G. T., "Proposal for the Miniaturization of Aerial Photography." PHOTOGRAMMETRIC ENGINEERING, Vol. XXII, No. 5, pp. 925–929.

Stone, K. H., "Air Photo Interpretation Procedures." PHOTOGRAMMETRIC ENGINEERING, Vol. XXII, No. 1, pp. 123–132.

1957. Babington-Smith, C., "Air Spy, the Story of Photo Intelligence in World War II," Harper, New York, 1957.

Cheney, T. A., "A New Interpretation of the Interpretation Situation." PHOTOGRAMMETRIC ENGINEERING, Vol. XXIII, No. 1, pp. 101–105.

1957. DeLancie, R., Steen, W. W., Pippin, R. E., Shapiro, A., "Quantitative Evaluation of Photo Interpretation Keys." PHOTOGRAMMETRIC ENGINEERING, Vol. XXIII, No. 5, pp. 858–864.

Heath, G. R., "Correlations Between Man's Activity and His Environment which May Be Analyzed In Photo Interpretation." PHOTOGRAMMETRIC ENGINEERING, Vol. XXIII, No. 1, pp. 108–114.

Lewis, G. K., "The Concept of Analagous Area Photo Interpretation Keys." PHOTOGRAMMETRIC ENGINEERING, Vol. XXIII, No. 5, pp. 874–878.

McLerran, J. H., "Photographic Interpretation—Its Significance in the Highway Program." PHOTOGRAMMETRIC ENGINEERING, Vol. XXIII, No. 4, pp. 755–762.

Seymour, T. D., "The Interpretation of Unidentified Information—A Basic Concept." PHOTOGRAMMETRIC ENGINEERING, Vol. XXIII, No. 1, pp. 115–121.

1958. Chisnell, T. C., and Cole, G. E., "Industrial Components—A Photo Interpretation Key on Industry." PHOTOGRAMMETRIC ENGINEERING, Vol. XXIV, No. 4, pp. 590–602.

Hedden, R. T., "Recent Developments in Photogrammetric Procedures and Techniques in ACIC." PHOTOGRAMMETRIC ENGINEERING, Vol. XXIV, No. 1, pp. 70–76.

1959. Dill, I. H., Jr., "Use of the Comparison Method in Agricultural Airphoto Interpretation." PHOTOGRAMMETRIC ENGINEERING, Vol. XXV, No. 1, pp. 44–49.

Green, N. E., and Monier, R. B., "Aerial Photographic Interpretation and the Human Ecology of the City." PHOTOGRAMMETRIC ENGINEERING, Vol. XXV, No. 5, pp. 770–773.

McDaniel, J. F., and Arntz, J. F., Jr., "Aerial Color Film in Photo Interpretation." PHOTOGRAMMETRIC ENGINEERING, Vol. XXV, No. 4, pp. 529–533.

1960. Hauser, H. F., Lt. Col., "Army Requirement for Aids to Assist Image Interpretation." Lecture given to USAEPG, Fort Huachuca, Arizona, 6 January 1960, 14 pp.

Hoffman, P. R., "Progress and Problems in Radar Photo Interpretation." PHOTO-

GRAMMETRIC ENGINEERING, Vol. XXVI, No. 4, pp. 612–618.
1960. Olson, C. E., Jr., "Elements of Photographic Interpretation Common to Several Sensors." PHOTOGRAMMETRIC ENGINEERING, Vol. XXVI, No. 4, pp. 651–656.
Sayn-Wittgenstein, L., "Recognition of Tree Species on Air Photographs by Crown Characteristics." Canada—Department of Forestry, Forest Research Division, Technical Note, No. 95, 1960, 50 pp.
Suits, G. H., "The Nature of Infrared Radiation and Ways to Photograph It." PHOTOGRAMMETRIC ENGINEERING, Vol. XXVI, No. 5, pp. 763–772.
1961. Abrams, T., "Aerial Photographs are Obsolete." PHOTOGRAMMETRIC ENGINEERING, Vol. XXVIII, No. 5, 1962, pp. 691–694.
1962. Allum, J. A. E., "Photogeological Interpretation." PHOTOGRAMMETRIC ENGINEERING, Vol. XXVIII, No. 3, 1962.
Frost, R. E., "Improving the Big Picture." PHOTOGRAMMETRIC ENGINEERING, Vol. XXVIII, No. 4, pp. 601–605.
Laurent, R. L., "Magnacard." Data Processing, Vol. IV, No. 10, pp. 33–38.
Mumbower, L. E., and Richards, T. W., "Image Information Processing for Photo-Interpretation Operations." PHOTOGRAMMETRIC ENGINEERING, Vol. XXVIII, No. 4, pp. 569–578.
Tomlinson, R. F., and Brown, W. G. E., "The Use of Vegetation Analysis in the Photo Interpretation of Surface Material." PHOTOGRAMMETRIC ENGINEERING, Vol. XXVIII, No. 4, pp. 584–591.
Van Lopik, J. R., "Optimum Utilization of Airborne Sensors in Military Geography." PHOTOGRAMMETRIC ENGINEERING, Vol. XXVIII, No. 5.

*New Requirements in Photo Interpretation**

THOMAS H. BIRD,
Jet Propulsion Lab., Pasadena, Calif.

ABSTRACT: *In this discussion some of the major factors which will place new and demanding requirements upon the photo interpreters of today are described. These requirements primarily result from an expansion of the conventional areas of application into the sphere of extraterrestrial investigations where these new requirements may prevail. No attempt has been made to establish how these new requirements will be satisfied as the principal effort has been directed towards a definition of the sources of these new requirements. New basic requirements for the interpreter will fall into five major classes, which are:*

1. *Need for a broader technical background in order to remain competent in the field of image interpretation.*
2. *Utilization of a technique for defining the image quality needed for specific tasks and the ability to evaluate specific systems in terms of useful image output.*
3. *Preparedness for interpretation of various sensor records and the need for a greater understanding of integrated sensor systems.*
4. *Utilization of non-stereoscopic photography of scales smaller than that used for most interpretation tasks of today which will direct the emphasis of the interpretation procedures to shift from image identification to the processes of imagery associations.*
5. *Ability to utilize highly sophisticated systems for the necessary data extraction and recording tasks.*

NEW requirements which will affect the photo interpreters of today are primarily results of advances in new fields of scientific investigations where the interpreters' talents may be required. One of the most important of these areas is in the field of extraterrestrial investigations. This is becoming very important to everyone at the present time.

As scientific knowledge and capabilities are expanded into these new fields, it becomes

* Presented at March 24–30, 1963 ASP-ACSM Convention, Hotel Shoreham, Washington, D. C.