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State-of-the-Art of Close-Range Photogrammetry

A review of cameras and photography, measuring instruments, and methods for applications.

INTRODUCTION

THIS REPORT PRESENTS a review of recent developments in, and applications of, close-range photogrammetry. It also gives an outline of possible and desirable developments in the future. The author is aware that only to a certain limited extent can this report attain such a goal.

ABSTRACT: *The activities of ISP Commission V include all phases of non-topographical photogrammetry: cameras, photography, graphical and numerical mensuration, data reduction, and presentation of results. Single metric cameras, stereometric cameras, and measuring equipment with a series of accessories constitute instrument systems which are very convenient for certain applications, e.g., architectural photogrammetry. The analytical approach for data reduction opens the doors for multicamera photography, rigorous least-squares adjustment, different models for the calibrations of interior orientation parameters, use of non-metric cameras, etc. Integration of measurement with succeeding data handling also is accomplished by digital analysis of data. Close-range photogrammetry is widely used in architecture and biomedical applications. A further increase in the use of photogrammetry as a measuring tool in production processes in industry and civil engineering is to be expected.*

The content is partly based on replies to an enquiry sent to the invited authors, and the panel members for the Commission V sessions of the ISP Congress in Helsinki 1976, and partly on the personal opinions of the author. It is perhaps unfortunate that all who have very kindly contributed have never had a chance to see the manuscript before the printing of this report. The author willingly accepts responsibility for all incorrect citings or interpretations from these many contributions. To offset this there will be a panel discussion on the subject during the Helsinki Congress, so interested parties will have an opportunity to promote their own ideas and have them discussed by their world colleagues. If this report is not an exhaustive survey of today's (July 1975) close-range photogrammetry, at least it will serve as a basis for discussion on the state-of-the-art and its future development.

International activities in photogrammetry are organized in seven commissions, each one dealing with a specific area of the subject. Commission V deals with non-topographical applications, which are all applications which cannot be classified as topographical (Commission IV) or interpretive (Commission VII). The Commissions I - III deal with questions related to photography, cameras, instruments, methods, and theory. This would seem to restrict the responsibilities of Commission V. The other commissions base their work almost entirely on aerial photography, but the non-topographical applications are very seldom, if ever, based on photography with aerial cameras. On the contrary, there is a series of cameras especially designed for non-topographical photogrammetry, as well as a series of plotters and data reduction instruments for these cameras. Also very often the results of a nontopographical photogrammetric measuring process differ considerably from those which are common in aerial photogrammetry because of the special requirements of the consumer. These requirements also necessitate the use of cameras that are not specifically designed for photogrammetric purposes, and the development of instrumentation, systems, and methods for data reduction that are unique to the application in question. This means that Commission V has the responsibility of treating problems related to all phases of non-topographical photogrammetry: cameras, photography, measuring instruments, theory, methods, presentation of results, etc. This fact is reflected in the assignments of the working groups of Commission V, namely:

(1) Analytical and Semi-Analytical Approaches in Terrestrial, Close-Range, and Micro-Range Photogrammetry
(2) Photogrammetric Potentials of Non-metric Cameras
(3) Metrical Aspects of Non-Conventional Imageries—Holographic and Thermal Imageries.

During the Commission V Symposium in Washington D.C. in 1974, a revision of the title and activities of the Commission was discussed. The president of the Commission proposed a change from the current wording of Non-Topographical Photogrammetry:

(1) Close-range and micro-range photogrammetry.
(2) Photogrammetry at extreme distances (Applications in Space and Astronomy).
(3) Photogrammetry of objects in motion and under deformation.
(4) Exploration of non-conventional photography, such as holography.

to the following:

Close-Range Photogrammetry: All aspects of close-range and micro-range photogrammetric systems, including data acquisition, reduction and processing, and with a scope encompassing conventional photography (metric and non-metric), and non-conventional imageries (holographic, thermal, x-ray, television, etc).

One might ask which of these titles is best. Non-topographical excludes terrestrial photogrammetry for mapping, while close-range excludes other applications when the range is limited by a certain distance, for instance 1000 feet as has been suggested by Karara.[14] However, of greater importance than the title is the real content, importance, and value of the problems treated by the Commission.

Cameras and Photography

Cameras used for close-range photogrammetry are divided into two groups, metric and non-metric. Karara[14,15] defines a non-metric camera as one that has not been designed especially for photogrammetric purposes, while Faig[7] has a more technical definition that such a camera has an interior orientation that is completely or partially unknown and frequently unstable. He also proposes a simpler definition by saying that a non-metric camera does not have fiducial marks. He also mentions a number of parameters used to define the interior orientation which include the location of the principal point, the principal distance or calibrated focal length, radial (symmetric) lens distortion, decentering (frequently considered in the form of its components, assymmetrical and tangential lens distortions), film deformation, and affinity. The traditional definition of a metric camera having "fixed and constant" interior orientation no longer holds, since there have appeared on the market several focusable cameras that definitely must be regarded as metric cameras. Examples are the Zeiss Jena UMK and IMK, Officine Galileo Verostat and Tecnoster, Sokkisha B-45, V-3, KSK-100, the Wild P31, and the Hasselblad MK70 with two of three lenses focusable. The TMK and SMK series from Zeiss Oberkochen now are equipped with a set of attachable lenses in order to widen the range of camera-to-object distance.

Metric Cameras

Perhaps the simplest way to classify cameras as metric or non-metric is by the existence of fiducial marks. This holds for the tables of metric cameras published by Carbonnell[2] and supplemented in[3], Karara[14] and[15], and Peczek[26]. These tables also contain information on the main characteristics of the more than 30 types of cameras. The focal lengths vary from 56 to 190 mm, the formats from 55-×-55 mm to 130×-180 mm, the cone angles from 33 to 88 gon, the aperature values from 3.5 to 64, and the exposure times from B to 1/500 sec. There is thus a fairly wide variety of types available to the photogrammmetrist. A dominant feature of metric cameras is that the radial distortion is so small that it often may be neglected for most practical applications. This has been a lens design criterion that, together with stability requirements, has ended in the fixed-focus cameras. Only during the latest decade has it been possible to design and produce focusable lenses with radial distortions and stability within the photogrammetric tolerances. The Zeiss Jena UMK has two types of lenses, one for the shorter and one for the longer, focusing distances. This development is welcomed because it opens the doors to many new applications of close-range photogrammetry. Because object size and accuracy requirements vary considerably, a great deal of flexibility is needed to obtain an optimal camera-to-object geometry.

A few new metric cameras have appeared during the last few years, for example, from the USA (DBA Systems Inc.), and Japan (Sokkisha). The European manufacturers primarily have developed a series of accessories for both cameras and plotting machines which provide the photogrammetrist with an instrumental system well-suited to certain applications such as, for example, architectural photogrammetry. The possibility of tilting the cameras (both single and stereometric) by predetermined angles is a common feature. This also means a standardization of the geometry during photography, speeds up the field procedure, and decreases the risk of blunders, compared to the type of cameras that have continuous tilt facility. This must be regarded as an advantage for routine work with a standardised production. On the other hand the flexibility of the phototheodolites and the cameras placed on theodolites is often necessary in order to have an optimal location and direction of the cameras when the object, its environment, and other conditions make it difficult or even impossible to use standardised methods.

Most of the available metric cameras are designed for the use of glass plates as the photograhic emulsion base. This is, of course, the best solution possible from the point of view of stability. This also provides a defined standard of flatness when treated in the proper way, and with the use of proper cassettes. For the most accurate types of photogrammetry, plates are a necessary prerequisite. On the other hand, there are several drawbacks with plates. They are not easy to handle. They are heavy. They must be transported with great care. They are expensive. Only a limited number of emulsion types are available. Delivery times are often long, and the shortest exposure interval is long. Several of these drawbacks are eliminated if roll film or cut sheet film is used, but then certain precautions have to be taken to flatten the film before exposure, and to control the stability of the film during the photographic processes and storage. With the Verostat, P32, Nikon TS-20, and the Zeiss Jena SMK cut sheet film in special cassettes may be used. The Zeiss Jena UMK, Wild P32, Officine Galileo Tecnoster A, and Hasselblad MK70 cameras are the only cameras that can be equipped with roll film magazines. The flattening of the film is, in the UMK and Tecnoster, provided by suction plates, while the others rely on glass plate in the image plane. The film deformations are controlled by four or five fiducial marks. The Hasselblad MK70 is the only camera having a *reseau* (25 points), which for digital data reduction yields an excellent means of image coordinate refinement. The roll film version of the UMK and the MK70 have automatic film transport, and the shortest exposure intervals are 3 and 1 seconds respectively. This facility is very convenient for remote-controlled firing, and for the recording or documentation or measuring of slowly moving objects or events.

The flatness of the plates is classified in three categories: standard, ultra flat (12.5 μm/inch), and micro flat (0.5 μm/inch). Ultraflat plates cannot always be obtained from stock, (the Wild Company now stock such plates as a service to their customers). Microflat plates must be ordered in sufficiently large numbers before production and even then one cannot be sure of delivery, which is dependent on the manufacturer's production schedules. The cost of such plates is very high and the use of them can only be advocated for projects where the utmost accuracy is required.

NON-METRIC CAMERAS

The use of non-metric cameras compared to metric cameras for photogrammetric purposes, has the following advantages and disadvantages according to Karara[15].

Advantages:
- General availability,

- Flexibility in focusing range,
- Some are motor driven, allowing for a quick succession of photographs,
- Can be hand-held and thereby oriented in any direction,
- The price is considerably less than for metric cameras.

Disadvantages:
- The lenses are designed for high resolution at the expense of high distortion,
- Instability of interior orientation,
- Lack of fiducial marks,
- The absence of level bubbles and orientation provisions precludes the determination of exterior orientation before exposure.

The increasing use of non-metric cameras for photogrammetric purposes is, to a great extent, due to the research and development, both within and outside the ISP, aimed at the elimination of these disadvantages which in most cases is accomplished by combined calibration and evaluation techniques. As pointed out by Faig[7], "the amount of object space control is directly related to the calibration and/or the evaluation approach, and to the accuracy requirements." He also divides the photogrammetric equipment systems, for non-metric cameras, into five groups according to the type of calibration that is included in the system.

Some of the disadvantages can be overcome by introducing fiducial marks, often very easily. Orientation aids such as spirit levels can also be arranged in the workshop without too much effort. The instability of the interior orientation can be difficult to reduce because this necessitates more severe alterations in the camera itself. Examples of this are the introduction of glass plates in the image plane and film flattening by hand-driven suction devices in the film magazines. When these suggested or similar alterations are made to the camera, it will be more or less completely rebuilt, and after a complete calibration, may be regarded as a metric camera.[31] However, because the stability of the camera and the reproducibility of the interior orientation is limited, Faig calls the calibration of such a camera "partial", even if all the parameters used for the calibration of metric cameras are included.

The other extreme to the calibration of non-metric cameras is the use of methods which do not require any calibration at all. One example is numerical and graphical rectification based on projectivity between the plane of the image and the plane of the object. Another example is the direct linear transformation (DLT) approach[1]. In both cases the solution is principally for the interior orientation of the actual images but the elements themselves are not explicitly obtained from the solution of the equation systems.

Between these two extremes of complete and no calibration, Faig introduces three other categories of calibration, namely: partial, self- and "on-the-job" calibration.

Partial calibration is usually performed in a laboratory with some kind of test area or target array.[30] It could conceivably encompass all the parameters of interior orientation used in metric camera calibration, but, as a rule, only some of them are used. The selection of parameters depends on the accuracy required and the data reduction procedures applied.

Self-calibration is based on multiframe photography and measurement of a larger number of unknown points. Parameters for the interior orientation are included in the adjustment of the observation equations. Because the redundant points are also unknown this results in certain geometric conditions being placed on the number and arrangement of photographs and points in order to achieve a strong solution.

"On-the-job" calibration also determines the interior orientation in the same adjustment as the other unknowns (exterior orientation and/or points) but in this case the solution is based on a sufficiently large number of well-distributed and known control points.

Self- and "on-the-job" calibration determine the interior orientation of the same photographs as used for the object measurement, which eliminates the effect of instability of the non-metric cameras. These types of calibration are often combined with a partial calibration for the radial distortion, which reduces the number of unknown interior parameters, and the number of observations necessary for a strong solution.

Another approach to the problem of calibration of non-metric cameras, which has not been used regularly in close-range photogrammetry, is the method of linear least-squares interpolation and the use of statistical prediction and filtering. This is used in aerial triangulation and digital models for contour line plotting. Several other applications including calibration have been demonstrated.[20] Closely related to this are the multisurface fitting methods described by Hardy[10] and Rauhala.[27] It would seem to be very worthwhile to try these methods with the use of non-metric cameras because they can reduce the effects of instability and non-reproducibility of the geometry of the images.

NON-CONVENTIONAL IMAGES

By non-conventional images is meant imaging systems that do not use a lens and an image plane and thus are not frame photographs based on the central projection of the object onto an image plane. To this group belong x-rays, scanning electron microscopes (SEM), TV-systems, different types of scanning images, digital images, and even panoramic and continuous strip photography, as well as holographic and Moiré techniques.

Most of the measurements made on these types of images are made by those other than photogrammetrists, such as physists, mechanical engineers, physicians, geologists, forresters, and so on. Except for the measurement of x-ray images, photogrammetric activities in the area of non-conventional images have been rather limited.

X-ray is from a geometric point of view very similar to conventional photogrammetry, because the imaging system very well realizes central projection, sometimes even better than lens-camera photography. The photogrammetric calibration of x-ray systems is performed by using the same methods as for non-metric cameras, the only difference being that the object test points are made of a material of different radiotransparency[9]. Complete, partial, and "on-the-job" calibration approaches are applied. There are, on the market, x-ray systems with double tubes and rapid cassette exchange mechanisms, which provide an excellent means for taking nearly simultaneous stereo photographs. However, the stereo photographs are usually taken with ordinary equipment and with a few seconds' time interval, moving either the tube or the object between exposures.

Calibration of scanning electron microscopes (SEM) using the self-calibration method has proved to be very efficient. Parameters for radial, tangential, and spiral distortions are introduced into the adjustment together with the scale factors, object orientation parameters and co-ordinates of points on the test object. The introduction of the distortion parameters has increased the accuracy of the mathematical model very much, which is of great importance for the three-dimensional technique with SEM.[8,24]

The present definition of the activities of Commission V includes space photogrammetry, which encompasses images from remote sensing systems. Many other commissions have dealt with this subject and the working group on "Geometrical Aspects of Remote Sensing" was formed under Commission III. The reader is referred to the reports from this group.[19]

The Moiré technique has been developed in Japan and a direct method immediately gives contours on the object itself. This can then be photographed using single or stereo cameras. Deformations can also be recognized very conveniently. Theory, instrumentation, and applications in medicine and industry are described by Takasaki.[29]

Holography and its potential for making measurements has been treated by many. (See Mikhail[25]) The interested reader is referred to the rich literature on coherent optics for a further study of this broad and expanding part of physics.

Measuring Instruments

Analogue instruments used in close-range photogrammetry can be divided into three groups:

1. Normal case plotters. They are often a part of a close-range photogrammetric system.
2. Universal first order plotters. These have fairly large ranges for ω, ϕ, κ, Z, c, and B, and are used for both aerial and terrestrial photographs.
3. Mapping plotters. These are designed for aerial mapping and accept vertical or nearly vertical photographs, and can sometimes be used for close-range photogrammetry.

Technical details for the first and second types are given and discussed in the literature.[2,3,14]

The metric and stereometric cameras from several manufacturers have adapters for tilting the cameras to predetermined angles. As a result some of the manufacturers also have developed a tilt correction device to be inserted between the plotter (stereo model) and the drafting table, so as to have the projection planes vertical or horizontal even for tilted photography, without the use of large ω-tilts in the plotter. This means that a universal plotter is no longer necessary for the evaluation of tilted models. This must be regarded as a great advantage for many architectural and civil engineering applications, where a graphical output is used for the presentation of the results.

The analytical instruments are widely used for non-topographical photogrammetry because of the use of non-metric cameras, and also because of the necessity for further treatment, in computers, of the primary photogrammetric results (object co-ordinates). This is, of course, due to the rich variety of objects and events to be measured and the necessity of flexibility in the solution of the measuring problems as such. By analytical instruments we mean devices for measuring image co-ordinates and, as a rule, the recording of these co-ordinates on a data medium for later input into a computer. Traditional photogrammetric monocomparators and stereocomparators are widely used. With few exceptions most instruments have plate holders for 23-×-23 cm photographs. In a majority of cases, close-range photogrammetry is based on smaller photograph sizes and this might possibly indicate a need for the construction of mini-stereocomparators.

For medical x-ray purposes Zeiss Oberkochen has produced the StR comparator, an instrument with measuring accuracy, viewing system, and output of results specifically optimised to suit the particular given conditions. A programmable desk calculator is an integral part of the system which means real-time calculation of desired quantites.

Similar in principle, but not as accurate as the monocomparators, are the digitizing tables, which can be used for large-image formats and not too high-accuracy requirements. This type of instrument could possibly be used for the measurement of some types of x-rays.

The analytical plotters have been used advantageously for close-range applications. These instruments give the project planner great freedom in the choice of cameras, orientations, co-ordinate refinement parameters, mathematical models, *and* output in digital or graphical form, using any desired projection. This has been thoroughly discussed by Jaksic [13].

Rectifiers have long been in use for non-topographical purposes, and recently modern orthophoto printers have been used for architectural photogarammery. See, for example Seeger[28] and Döhler[5].

The analytical approach can offer practical methods if there are computers available. Today we have at our disposal a broad spectrum of computing machines ranging from pocket calculators to desk calculators and mini computers to large general-purpose computer systems. This is not the place to go into the details of computer development but it must be pointed out that it has been fundamental to the increasing use of close-range photogrammetry. Today's computer technology already provides the photogarammetrist with a variety of hardware and software and the future will certainly provide him with even more flexible solutions to his calculation tasks. This holds for programming, and intrinsic mathematics as well as for the time needed, which means real time presentation of results. The instrument manufacturers have also taken an interest in and provided software for non-topographical photogrammetry[35].

Methods for Applications

Normal Case

Many applications, perhaps a majority, within non-topographical photogrammetry are rather straight-forward from the point of view of methodology. Photographs are taken with stereometric cameras or with single cameras according to the normal case. The evaluation process is thus simplified for graphical plotting as well as for analytical reduction. As the interior and relative orientation and often several or all absolute orientation elements are known, the number of control points can be kept to a minimum. Two points are minimum for scaling and locating the stereomodel and they are preferably positioned as far as possible from each other within the model. If a comparatively flat model is parallel to the picture planes the scale correction is made by a base change. If the model is perpendicular to the pictures the scaling often is done by a $\delta\phi$-change, because this is well correlated with a principal point displacement, which often is critical for the small "base-height" ratios that are common in many cases of architectural and civil engineering applications.[19] Use of metric cameras and glass plates makes image-coordinate refinement unnecessary for moderate-accuracy requirements and the output from the plotters in graphical and/or numerical (model coordinates) form is often what is needed for the consumer. In case of comparator measurements, a reduction to model coordinates is very simple and can be programmed even for desk calculators.

Graphical Results

For graphical presentation of results the manufacturers produce systems of camera and plotters for such straight-forward close-range photogrammetry. Carbonnel[2] has divided these systems into three groups according to the size of the objects to be measured and has given samples of the marketed systems. The projection planes for the graphical plotting can be chosen rather freely, especially with the use of tilt calculators now offered by the manufacturers. New types of projections called Geometrals and Axonometric projections are demonstrated by Carbonnell [4] for architecural purposes.

These new types of graphics are very illustrative and can increase the interest for photogrammetry. The possibility of choosing the orientation of sections, profiles, and contours is for engineering and industrial purposes also a means of widening the use of photogrammetry.

NUMERICAL RESULTS

Although, in practice, the majority of cases make use of the analogue approach with graphical output, research and development efforts are devoted primarily to the analytical reduction of measured image coordinates, if one is to judge from the literature in the field. The availability of computers and the desire to use non-metric cameras even for accurate measurements have increased the development of analytical methods. The use of the photogrammetric data for further calculations, data analysis, data banks, etc., has also promoted analytical methods. Further development in the future towards greater integration between the photogrammetric data acquisiton and reduction phases on the one hand, and the succeeding data analysis on the other is to be expected. In order to reach this, close co-operation between photogrammetrists and consumers is needed. The classical photogrammetric methods (analoque or analytical) are not always applicable and requirements of potential new consumers are challenges to all photogrammetrists. We must, however, not be too ambitious and measure everything photogrammetrically. There are other methods and the merits of different approaches have to be judged so as to optimize the entire process of which the measurement often is just a minor component.

The analytical approach can, as mentioned above, be used in the rather simple case where interior and exterior orientation are known, but its advantages and versatility become much more pronounced in the most general case of photogrammetry in which a simultaneous solution incorporates the interior and exterior orientation elements of all photographs and the space co-ordinates of object points, all as unknowns.

The nature of measurements is point-by-point where mono- or stereocomparators are used. Depending on the final output requirement this can be more or less convenient. It can happen that the photogrammetric phase of the job is best solved by analytical methods but the required result is best presented in continuous form. In such a case the techniques of digital modelling, surface smoothing, prediction and filtering can be aplied. This has been discussed in relation to non-topographical photogrammetry by Wong [34] and applications are demonstrated for several biomedical cases by others[21, 16,17].

By its nature photogrammetry is a versatile and convenient tool for studying objects in motion. There are several industrial and civil engineering examples, most of which belong to the analytical group. Both mono and stereo methods can be applied for objects moving in one, two or three dimensions. The movements can be very slow, e.g., structural deformations[6,32]. They can be rapid, e.g., vehicle studies[33], or they may be termed high-speed, e.g., ballistics, aerodynamics, bubble chambers.

More uncommon projections are found in electron microscopy in that the principal distances are very long, infinite, or even negative. Photogrammetry can still be applied but of course not in the traditonal way. Kratky has given mathematical solutions.[22,23]

The accuracy of different close-range photogrammetric procedures is often determined by experiment and check measurements. For a large number of more-or-less standardized methods this has given us experience and simple rules-of-thumb for judging the accuracy in a specific case. For other methods, more sophisticated means are applied to determine the accuracy of the results. In some methods a rigorous adjustment of unknowns also includes the calculation of standard errors. In other cases, well-surveyed test fields are used, as in the experiments performed by Hottier[11,12]. For a single stereomodel and analytical data reduction he has found a considerable decrease of inaccuracy

- when the number of replicated settings on the same target is three instead of one (16 per cent decrease),
- when the number of targets defining each point is three instead of one (30 per cent decrease), and
- when the number of frames on each station is three instead of one (38 per cent decrease).

Further, Hottier discusses the optimum combination of settings, targets and frames as well as the base-height ratio.

CONCLUSIONS

Photogrammetry has been used for a great many different non-topographical applications. The range of images goes from electron microscopes to space cameras. Applications are found in the most diversified disciplines. The development of metric camera systems and evaluation equipment, as well as the increased use of analytical data reduction and computers, have been fundamental to the recent progress in close-range photogrammetry. Reading the literature on the subject, one finds the statement "Everything that can be photographed can also be measured" to be true in more and more cases. If requirements on accuracy, time, cost, type of output, etc. can be optimized, there will be an increased use of photogrammetry as a measuring tool in the future. Much effort has been devoted to problems connected with accuracy and type of output, while the time and cost parameters have not been studied to the same extent. They are, however, very critical where a method is to be used in production. A further integration of photogrammetry in the production process has to be made so as to widen the practical applications of the art.

Architectural photogrammetry is widely used and even has its own organisation, the International Committee on Architectural Photogrammetry (CIPA) which was established by the International Society for Photogrammetry (ISP) and the International Council on Monuments and Sites (ICOMOS) in 1970. Another field in which great strides are being made to apply and integrate photogrammetry is the biomedical. The International Commission V Symposium 1974 in Washington was entirely devoted to this theme. A third field of great interest is industrial and civil engineering applications. There have recently (1975) been symposia organized in Birmingham, the U K, and Urbana, Illinois. Further activities within this third field will be welcomed so that it may become as well established as the first two. The potentials of today's close-range photogrammetry are such that further development is most probable. Joint efforts by photogrammetrists and users in industry are necessary, and they will be successful, if made.

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Notice to Contributors

1. Manuscripts should be typed, double-spaced on $8\frac{1}{2} \times 11$ or $8 \times 10\frac{1}{2}$ white bond, on *one* side only. References, footnotes, captions—everything should be double-spaced. Margins should be $1\frac{1}{2}$ inches.
2. Ordinarily *two* copies of the manuscript and two sets of illustrations should be submitted where the second set of illustrations need not be prime quality; EXCEPT that *five* copies of papers on Remote Sensing and Photointerpretation are needed, all with prime quality illustrations to facilitate the review process.
3. Each article should include an abstract, which is a *digest* of the article. An abstract should be 100 to 150 words in length.
4. Tables should be designed to fit into a width no more than five inches.
5. Illustrations should not be more than twice the final print size: *glossy* prints of photos should be submitted. Lettering should be neat, and designed for the reduction anticipated. Please include a separate list of captions.
6. Formulas should be expressed as simply as possible, keeping in mind the difficulties and limitations encountered in setting type.

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As we have assembled at the site of one of nature's scenic wonders for the purpose of honoring a distinguished American citizen, we are participating indeed in an event of lasting historical significance to the organizations involved by establishing this monument. Our gathering is an honest, patriotic, and cultural service which we render to our nation at a time when revolting spirits are at work, with the aim to desecrate many of the coveted customs, beliefs, and institutions of our civilized community.

As professionals in the arts of surveying and photogrammetry, we are privileged to serve our country by being licensed to cover its great expanse with a strong and durable fabric of monumented landmarks of various descriptions, upon which the development of technical, economical, and social progress may be ascertained in a lawful and coordinated manner.

Today we have the privilege to unveil a monument of a different kind and of still greater significance. It bears the name of a great promoter of our science and our profession. The inscription on the plaque embedded on a truncated pyramid erected on solid rock of granite reads as follows: "Colonel Claude Hale Birdseye—1876-1941—Explorer, Geographer, Surveyor, the first Chief Topographic Engineer of the U. S. Geological Survey, 1919, and the first President of the American Society of Photogrammetry, 1934.

"He headed a geological survey through the Grand Canyon in 1923, to acquire information on the hydrography, topography, and geology of the Colorado River. This daring exploration provided scientific data that contributed to the prudent use of the river's waters for the production of energy and the economic development of several western states."

This brief characterization of Col. Birdseye's accomplishments points to a long and amazing story of his lifelong service to the U. S. Government and at the enormous impact that the successful accomplishment of his missions has had on the control of the entire Colorado watershed and on the cultivation of vast areas of arid lands in seven States bordering the river, and in California. This was one of the main reasons that the Board on Geographic Names, that is, the authority which controls the assignment of names to geographic features on U. S. maps, decided to name the pinnacle at the western end of the spur extending from the plateau of the Shiva Temple, the "Claude Birdseye Point."

From our vantage point this pinnacle can be clearly recognized (under favorable atmospheric conditions) at a distance of 8 miles against the darker colored background of the Canyon's north rim.

We owe the creation of the Birdseye Monument to the initiative of ASP's Board of Directors of 1973, to the U. S. Geological Survey under the leadership of its Chief Topographic Engineer, Robert H. Lyddan, and to the friendly cooperation of the National Park Service

This monument, carved by a skilled craftsman out of rocks of the Granite Gorge, and its plaque, artfully designed and cast of durable metal, shall stand here as a lasting beacon for courage and devotion, wisdom and noble qualities, which have been the outstanding characteristics of the man whose name it bears. It shall lend guidance and inspire ambition to present and future generations who pass by this point and remind them of the example given by Col. Claude H. Birdseye, Doctor Honoris Causa of his Alma Mater, the Oberlin College, who named him in the Award Inscription: "Traversor of Uncharted Ways of Rivers and Air, Recorder of the Eagle's Vision for the Service of Mankind."

I wish to express my personal gratitude and respect to the men of the U. S. Geological Survey and of ASP for having actively pursued the concept of this monument and having given it the simplicity of appearance and the ruggedness of character which is so ultimately commensurate with the person it commemorates. And as it stands here also as a symbol of fortitude, it is a fitting and lasting contribution to the Bicentennial celebration of our nation.

Finally, I have the honorable task to say a few words on behalf of the living members of the Birdseye family. Col. Birdseye's wife, Grace Whitney, is the mother, the grandmother, and the great-grandmother of a remarkable close-knit family of faithful, hardworking humanitarian people. Mrs. Grace Birdseye, now in her high 90's, has followed with deep emotion the events that have led to this ceremony. Although her physical condition does not permit her attendance, she is in spirit with us here today. Recently she has required the intense care by her daughter, Florence Sweigart. Understandably, she cannot personally express the gratitude of

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