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The Chicken or the Egg

A statement of a problem in instrument development may correspond to the egg, and the ideas for the solution resembles the chicken.

(*Abstract on next page*)

Introduction by *R. T. Shone*, Panel Moderator: The theme of the 1966 Los Angeles Semi-Annual Convention was *A Time for Appraisal*, and this panel concerned itself with the research and development aspects of this subject. About two choices are available for the manner of presenting the subject. One can attempt to appraise research and development in photogrammetry as a whole. Alternately, one can present specialized subjects within the broad field for detailed analysis without any attempt to cover the whole subject comprehensively. The latter choice allows one to be specific within the short time period available and seems to be the best approach. Therefore, each of the panel members has presented a short paper on a specific subject with which he is personally concerned. Three of these papers are contained in the following pages.

The amount of activity in photogrammetric instrument research and development has been accelerating rapidly since World War II. The apparent results have been most dramatic in the last ten or twelve years. In reviewing the situation, however, one develops some concern with the efficiency of our methods.

This paper is such a review. It is specifically concerned with photogrammetric instrument development, and research leading to development. The paper is further restricted to a primary purpose of reviewing R&D methods. Individual developments are mentioned as examples only and no attempt is made to present a comprehensive list of all significant recent developments. Emphasis is placed on the "problem definition" and "selection of objectives" functions.

Historical References

It is interesting first to review very briefly what some others have had to say in appraising the status of research and development in photogrammetry.

Eleven years ago many of us attended the ASP meeting in Southern California where Mr. George Hardy (1955) presented a paper titled, "The Future of Photogrammetry." A growth in the use of first order plotters (for commercial mapping) was predicted during the following few years. The importance of convergent photography was mentioned, as were the problems and cost in obtaining horizontal and vertical control. In the latter case, Mr. Hardy recommended the use of auxiliary instrumentation such as the Galileo Solar Periscope.

I am sure that Mr. Hardy will agree that there has *not* been a significant increase in the use of conventional "first-order plotters," at least in the United States. *First-order plotter* has lost its meaning! Professor Schermerhorn states on page 643 of the Third Edition of the Manual of Photogrammetry (1966): "The most popular classification, that of first-, second-, and third-order instruments, cannot be accepted for scientific use. It suggests a difference in precision which, especially comparing some so called second-order instruments with first-order machines, does not exist."

Dr. Lyle Trorey commented (1956) on developments and trends in photogrammetry from 1946 to 1956 and projected his thoughts

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into 1966. He predicted that there would be a great increase in importance of analytical bridging of control by 1966. He further pointed to a weak link in his prediction which was that a suitable coordinate measurement instrument was not available. We note today that much development has indeed been completed since 1956 on instruments for photographic coordinate measurement.

Perhaps the best known paper appraising the status and future of photogrammetry was presented at the Annual Meeting of the Society in 1959 by Dr. Robert Colwell. Looking 25 years ahead, automated plotting instruments of greater optical and mechanical simplicity were envisioned. He predicted that specialized equipment would be designed for particular problems in photo interpretation. Some examples included comparison viewers and conference interpretation techniques. There was an implication that much would be accomplished before the end of the 25-year period and a definite statement that the human eye and brain will still be needed in 1984 for identifying and interpreting images on photographs. He further stated that the human map plotter operator will not be replaced by automation in such problems as precise topographic mapping of tall, dense forest areas.

Nothing has occurred since 1959 which would cause one to doubt Dr. Colwell's conclusions.

ABSTRACT: *This paper appraises research and development methods in photogrammetric instrumentation. Emphasis is placed on the "problem definition" and "selection of objectives" functions. The argument presented is that although photogrammetric instrument research and development activities are producing significant results, still more can be accomplished for the effort being expended. One source of difficulty is in establishing development objectives. It is suggested that more use be made of the interdependence of such objectives with instrument design concepts during the exploratory development phase.*

RECENT ACCOMPLISHMENTS

Now that we have reviewed some past attempts at appraisal of photogrammetric instrumentation, let's try some appraising ourselves. No attempt is made to present a complete listing of recent accomplishments. Such listings have been published as recently as two years ago (Nowicki 1964, Esten 1964, Schmid 1964, Thompson 1964).

First are listed some of the mapping instruments that have been developed, largely since the 1955 semi-annual ASP meeting in Los Angeles. These are shown in Table 1. This, of course, is not the end of the list, but 30 instruments are sufficient to substantiate that this has been a most active period in plotter development.

Table 2 is a similar list of comparators and stereo point-markers. Twelve new instruments are sufficient to make the point that this has been a most active area also.

A list of some of the direct-viewing stereoscope developments in this field since 1955 is shown in Table 3.

As one delves more deeply into the subject, the discussion is becoming more specific. I started with photogrammetric instrumentation research and development and then narrowed the discussion to three categories: plotters, comparators and point markers, and direct viewing stereoscopes. This was done to confine the scope of the paper. However, the subjects presented are representative of all research and development in photogrammetric instrumentation. Although they may not always be the most important, they are certainly among the more interesting examples that could have been selected.

Reviewing the impressive list of plotter developments, my original question immediately comes to mind. How efficient has all of this effort been? Have we really made as much progress as it would appear at first glance? Looking over the list of 30 developments, how many are being used in significant numbers in production mapping operations?

Only five or six seem to have been unnecessary. The remainder either have achieved a significant place in mapping operations, are too new to receive a final judgment, or at least have led directly to another more significant development. Although your list of insignificant developments may differ from mine, we should agree that it is a short list nevertheless. The appraisal of recent developments looks favorable as we proceed more deeply into the subject.

TABLE 1. REPRESENTATIVE MAPPING PLOTTER DEVELOPMENTS

Gamble Plotter	Zeiss Jena—Stereotrigomat
T-64A Orthophotoscope—USGS	Galileo Stereosimplex II-C
Twinplex System—USGS	Kern PG-2
Balplex Plotter—Bausch & Lomb	Wild A-9 Autograph
Zeiss Supragraph	Wild B-8 Aviograph
Zeiss Aeromat	Wild B-9 Aviograph
AMS-Belfort M-2	Military High Precision (Kelsh Type)
Kelsh K-5 Plotter	Kern PG-1
Balplex 120° Projector	Thompson WattsII—Hilger Watts
Kelsh 120° Projector	Galileo Stereocartografo V
Wild WH-6 Projector	SOM Stereophot
Stereomat I and II	Nistri RA/II
B-8 Stereomat—Autometric	Digital Automatic Map Compilation System
AP-1, 2, AP/C—Bendix-Nistri	SOM-BABOZ Precision Plotter
AP-14—RADC-Librascope	
UAMCE—GIMRADA—Bunker Ramo	

Similar success ratios are found in comparators, point-marking instruments, and direct-viewing stereoscopes. It is beyond the scope of this paper to examine other photogrammetric instrument developments but, if we were to do so, many would show similar levels of activity and success.

Why then do I doubt the efficiency of our efforts? My argument is that with all of the effort expended, we should have accomplished even more by 1966. We have developed some overlapping instruments, some unnecessary instruments, and followed too many "blind alleys". I submit also that one of our greatest technical difficulties has been in defining the problems to be solved and setting objectives for development programs.

DESIGNING THE DEVELOPMENT OBJECTIVES

How can we improve our performance in defining problems and establishing development objectives? We must solve first the "which came first the chicken or the egg" problem. In this case, a statement of the development problem can be said to correspond with the egg, and ideas for problem solution correspond with the chicken. On one hand is the functional requirement needing a solution. On the other is a complex situation resulting from the researcher's ideas on what may be feasible.

Some researchers attempt to develop functional requirements for an instrument independent of the solution. I attempted this myself a few years ago as part of the system design group on a large program. Even though the resulting "Design Criteria Specification" may have looked like a functional requirement, it was often just a few researchers' ideas about the state of the art in the scientific fields related to the instrument design. I found this to be a situation which was unlikely to produce a good specification and found it necessary to develop instrument con-

TABLE 2. COMPARATORS AND STEREO POINT MARKERS. REPRESENTATIVE RECENT DEVELOPMENTS

Wild STK-1
Nistri TA3/P & TA1/P
Zeiss PSK
NRC Monocomparator
Link-GIMRADA—Automatic Pass Point Measuring and Marking Instrument
Mann 880 Monocomparator
Hilger-Watts Stereocomparator
SOM Stereocomparator
Zeiss Jena Stecometer
Optomechanism 620
Wild PUG-2
Bausch & Lomb-GIMRADA—Variscale Stereo Point Marking Instrument

TABLE 3. REPRESENTATIVE DIRECT VIEWING STEREOSCOPE. DEVELOPMENTS COMPLETED SINCE 1955

Bausch & Lomb 5-Inch Variable Power Scanning Stereoviewer (AR-51A)
Bausch & Lomb Variable Power Scanning Stereoviewer (AR26A, AR91A)
Bausch & Lomb Zoom 70 (AR42B)
Wild MSTK Stereoscope
Bausch & Lomb Zoom 95
Bausch & Lomb Versatile Stereoscope
FMA Wide Span Zoom Stereoscope
Elgeet-Olympus SZIIID
Bausch & Lomb High-Power Stereoviewer
Bausch & Lomb Dual-Viewing Stereoscope
Zeiss-Jena Interpretoscope
Optomechanisms 387 Stereozoom Viewer

cepts in conjunction with establishing the functional requirements.

The latter procedure agrees with Philosopher John Dewey's problem solving sequence as shown by Figure 1 (Hall 1962). One can start the problem solving sequence at any point in the loop, which can operate in either direction, and can be entered at any point. We can start the solution of a problem (the design of a new instrument in our case) with an idea, an evaluation, or a problem. One cannot claim that any one of the three components of the loop is more important than, or should precede, the others. The double arrows in each path suggest the feedback characteristics of the loop. Therefore in this analogy, the answer to "which came first" is either the chicken or the egg.

It has been said that creative technology consists of research, systems engineering, development, manufacture, and operation (Hall 1962).

The functions of "problem definition" and "selection of objectives" are contained within systems engineering. The word "system" means something different to almost everybody. An accepted definition (Hall 1962) is that a system is a "set of objects with relationships between the objects and between their attributes". All of our instruments should be systems, according to this definition.

Applying the terminology of system engineering to the simple illustration of the problem solving sequence results in the diagram in Figure 2. The loop can be entered at any point as before.

The purpose in all this has been to attempt to define clearly the exploratory development process with which we are all more or less familiar. The proper process is a loop between problem solving functions which must be iterative as well as multi-directional. Specifically we cannot write meaningful final development objectives for a new instrument without having synthesized and analyzed the instrument concept. We can now restate the "chicken and egg" problem as "which came first the instrument concept or the development objectives". As before, either may come

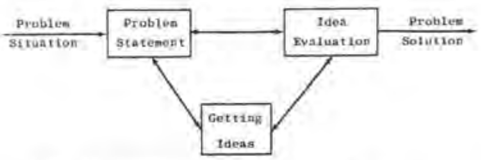

FIG. 1. Dewey's problem-solving sequence.

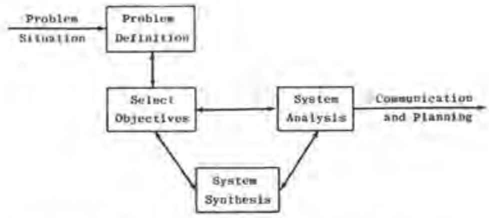

FIG. 2. Exploratory development-solution sequence.

first but one does not exist in final form without the other also being nearly in final form.

EXAMPLE

A generalization of this type is sure to be misinterpreted unless it is "spiced up" a bit with some "juicy, bad" examples. Unfortunately any real example in photogrammetry would start unnecessary controversy. Hence I have selected a very simple hypothetical one concerning a stereoviewing system. In the interest of simplicity—not realism—the function of "problem definition" is assigned to the Sales organization of a company and all other functions to the Research and Development organization of the same company. Now let's try a few loops.

Problem Definition—(Refer to Figure 2.) Sales says a stereoviewer is needed for rapid screening of roll film aerial photography. Viewing must be in stereo of adjacent 9 by 9 inch frames. Overlap varies between 50 and 70 per cent. Flight direction need not be parallel with the long direction of the film roll. High contrast resolution of the taking system is said to be such that important information may be packed as densely as 100 line pairs per millimeter over the full format.

Select Objectives—In the real world, R&D would probably say that "sales has gone off the deep end again". Assuming, however, that they take the problem seriously, there immediately would be several loops between the "problem definition" and "select objectives" functions to determine a first set of objectives. In addition there would be much discussion concerning whether a less special purpose problem would be more appropriate. Let's assume the following set of objectives:

View areas as large as 9 by $6\frac{1}{2}$ inches stereoscopically at one time at magnifications up to 25 times. High contract resolution up to 200 lines per millimeter (to provide some allowance for the unknown low contrast characteristics of the input photography).

Stereo base separations—in X about 10 inches maximum and up to $4\frac{1}{2}$ inches in Y. Optical image rotation.

Other optical, mechanical, and electrical details all of importance but not considered here.

Synthesis—As another concession to simplicity, only two types of systems will be considered, conventional direct viewing stereoscopes and conventional stereo projection. The objectives immediately rule out a direct viewing system but a projection system is theoretically possible. The screen size would be as large as 180 inches in one direction and the total optical path length might be over 50 feet.

Analysis—Nonsense! No one can "screen" fine detail on a 180 inch area. At this point one of two things may happen if the objectives are inflexible. Either the project dies or a "monster" instrument is developed. Both of these possibilities have occurred in real examples. Let's continue, assuming flexible objectives.

Objectives—Suppose we ask for half as much resolution?

Synthesis—90-inch screen.

Analysis—Still nonsense!

Synthesis—Let's try a new approach wherein a projection system is 2X giving a largest screen dimension of 18 inches. Resolution is 20 lines relative to the film. The direct viewing stereoscope position is indicated by two points of light on the projection screen, one for each viewing area. If the light points are over corresponding imagery, they appear as one on the screen. The stereoscope may be moved to scan over each stereo pair and has a resolution compatible with the photography.

Analysis—This instrument, while not meeting the objectives as stated, should be a useful compromise in a relatively inexpensive form.

Objectives—All original objectives would be met except that resolution during initial screening would be an order of magnitude lower.

This change in objectives would then be examined to see if the problem could be redefined to fit the instrument concept. In more complicated cases there would be further compromises and the loop would continue. This crude example should suffice to help establish the point that the normal exploratory development sequence should be allowed to function if a sensible result is to be expected.

Conclusions

In much of our research and development leading to new photogrammetric instruments, we do not follow logical principles of problem solving. In too many cases we attempt to separate the "problem definition" and "selection of objectives" functions from the remainder of the solution sequence. The result may be unrealistic objectives and often the developed instrument is unsatisfactory. The primary purpose of this paper has been to point out this source of development inefficiency.

Several factors contribute to the problem. Among these is the often sharp distinction between those concerned with instrument development and those concerned with instrument operation. For example, most schools concerned with photogrammetry in this country cover only the *operation* of instruments, if instruments are covered at all. Some of you may insist that instrument development is really not part of photogrammetry anyway. An argument of this type is very uninteresting. The important point is that more photogrammetrists are needed who can participate in developing the instrument concept.

Another factor contributing to the problem is that the "problem definition" and "selection of objectives" functions are often performed in one organization which is separated from the organization concerned with remaining functions. This often is necessary with government sponsored development programs, for example. Some new techniques are helping to alleviate the contribution to the problem from this factor, however. These include requirements for an approved Design Analysis prior to proceeding with the remainder of the program. It is suggested that the scope of such analyses be increased to include the complete problem solving sequence.

Summary

In summary, this paper has been an appraisal concerned mostly with a specific problem area in photogrammetric instrument development. The argument presented is that although photogrammetric instrument research and development activities are producing significant results, still more can be accomplished for the effort being expended. One source of difficulty is in establishing development objectives. It is suggested that more use be made of the interdependence of such objectives with instrument concepts during the exploratory development phase.

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Articles for Next Month

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Floyd F. Sabins, Jr., Infrared Imagery and Geologic Aspects
Richard A. Bradie, SLAR Imagery for Sea Ice Studies
Robert F. Holmes, Engineering Materials and Side-Looking Radar
Donald U. Wise, Radar Cross Sections and Geologic Features
Richard Blythe and *Ellen Kurath*, Infared and Water Vapor
James P. Latham and *Richard E. Witmer*, Waveform Analysis of Multisensor Imagery
Alphabetical List of Members of the American Society of Photogrammetry

Articles in Other Photogrammetric Journals

Zeitschrift fur Vermessungswesen, Vol. 92, No. 2, February 1967

Ferdinand Determeyer, Land Consolidation and Photogrammetry
Walter Reimann, The Suitability and Application of the Hommel 2-meter Scale Comparators for Surveying (level rods)
Naguib F. Danial, The Various Possibilities of Measuring Angles in All Combinations
W. Jansen, Boundary Regulation—Expropriation?

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F. V. Drobyshev, The Mechanical Coordinatograph
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V. A. Gorbatov and *E. D. Tamitsky*, Studying Color Differences in Certain Geological Features from Air Photos
K. A. Zykov, Photorectification using Orientation Elements
V. I. Novikov, Photogrammetric Levelling in Highway Location Surveys
A. I. Obiralov, The Stereoscopic Method of Assembling Stereo Mosaics
V. N. Balandin and *G. B. Shoikhett*, Experimental Evaluation of Radio Ranging Accuracy in Photogrammetric Mapping
M. V. Shulmin, On the Technique of Making a 1:25,000 Map of Plain Terrain with Sparce Ground Control

Erratum

Mention of Consorcio Nacional Aeromapas Seravenca, C. A. of Caracas, Venezuela, was inadvertently omitted from the Services and Equipment Guide of the January 1967 issue although the firm has been a Sustaining Member of the American Society of Photogrammetry for many years. They should have been listed in the Services section under Field (Control) Surveying, Photogrammetric Surveying, Photographic Interpretation, Photographic Processing, Aerial Photography, etc. A description of the firm is included on page 537 of the July 1967 issue.

See announcement of 1968 Congress in Switzerland on page 658.