basic design is quite similar to other, larger calibrators. The problems encountered during its development were not unusual. However, the application of calibration techniques to small, amateur type cameras is unique. The uses of this instrument and others similar to it are manifold.

One case in past history is a good example. When Admiral Byrd went to Little America in 1946 he carried a number of K-17 cameras which had been fitted with special lens cones in which the fiducial marks had been permanently mounted. Thus these cameras contained all of the elements of interior orientation. Due to time limitation, it was impossible to calibrate all of these cameras before leaving the United States. Therefore, it was planned to take the photography and calibrate the cameras later on. However, on one flight the plane developed engine trouble and everything movable was thrown overboard including the cameras. Although the film was saved, it was not usable for mapping purposes without the calibration data. If this calibrator had been available at that time, the calibration exposures could have been made in a matter of just a few hours and preserved for use with the film regardless of what happened to the camera.

This is only one incident of many which point up the requirement for this type of calibrator development. Although the development of the calibrator is not complete at the time of this report, it is believed that upon completion it will be a very valuable piece of equipment.

*A Reappraisal of Photogrammetric Research**

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ABSTRACT: *Progress in any scientific field is the direct result of research —whether it be basic or practical. Progressive-minded photogrammetrists should therefore be concerned with the status of research in our profession, particularly in view of the fact that a recent survey revealed 3 out of 4 mapping organizations believe the current research effort in photogrammetry is not adequate. The author presents various data compiled from a research survey and analyzes the results. Included in the presentation is a list of research items that the mapping industry feels require the greatest attention, and also some opinions as to what steps should be taken to improve our research activity. As a matter of further interest to all, the three outstanding developments in photogrammetry in the past ten years, based on a consensus of opinion, are named.*

THE value of research in our economy is almost universally recognized today. It has become the key to progress and is a primary determinant in the economic future of industry. The expenditure of about 5.4 billion dollars in one year[1] for research and development in the natural sciences in the United States, representing roughly 1.5 per cent of the gross national product, is clear testimony to its acceptance. There are many concepts of research, but for the purpose of this paper it shall be considered as effort expended in the creation or improvement of products or techniques.

In order to determine how the photogrammetric profession feels about research, and to gather some facts on the status of this phase of our vocation, the author, as a member of the Research Committee of

[1] For year 1953, the last year for which results are available.
Source: "Reviews of Data on Research & Development," National Science Foundation, Dec. 1956.

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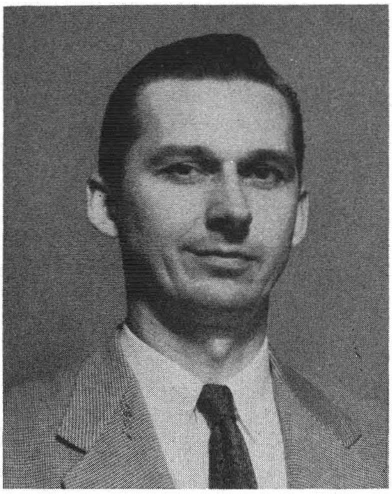

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the Society, conducted a survey by sending a questionnaire to the Sustaining Members of the American Society of Photogrammetry, Government mapping organizations, and educational institutions concerned with photogrammetric research in the United States. The results of the survey are the basis for this paper. It is believed that the assembled data give a fairly accurate picture of our "research thinking" inasmuch as it represents replies from 100 per cent of Government mapping organizations, where most of the research is done, 62 per cent of the colleges, and 68 per cent of commercial firms that were contacted.

The replies to the questionnaire revealed unanimity in only two counts: these are, (1) that photogrammetric research in the past ten years has definitely "paid off," and (2) that continued research is needed. Three of the four of those that had an opinion, however, stated that our current research effort is *in*adequate; this fact bears investigation. Inadequacy implies either insufficiency or inefficiency. Let us first analyze the former.

If the photogrammetric industry wants to keep pace with the rest of industry in the United States, it should be spending about three per cent of net sales on research.[2] Of course, a percentage factor such as this is only a general guide inasmuch as research expenditures should be determined by a judicious appraisal of a firm's needs and resources. Nevertheless, it is a point of departure. Thus, based on Professor C. L. Miller's recent survey,[3] if private industry is using photogrammetric services to the extent of approximately 9 million dollars a year, about $270,000 of its annual funds should be directed towards research. The research survey showed that private industry spent about $260,500 in 1956 for photogrammetric research. This figure is admittedly controversial because of differences in accounting methods. It does, however, give us some idea of the extent of research in private photogrammetric firms, and reveals that such firms are apparently spending an amount for research that is in keeping with the national average for all of industry.

The survey further revealed that the major Government mapping agencies were spending a little under 1 per cent of their funds on photogrammetric research, or a total of approximately $1,000,000 in 1956. Government-wide expenditures for all types of research and development in fiscal year 1955[4] amounted to 4 per cent of the total budget; this is four times as much, percentagewise, as was spent on photogrammetric research. Five educational institutions reported a total expenditure of $61,000 for photogrammetric research. No association between total budget and research expenditures in the colleges could be made.

In comparing the total funds spent, with the total number of photogrammetric employees of all types, we find that the colleges are spending $1,850 per employee; the Government—$500 per employee; and commercial firms—$198 per employee.

Of all the suggestions received for improvement in our research effort, the one that appeared most often, particularly from the schools, was for more money and increased facilities. The educators pointed out that both private industry and the Government stand to profit by sponsoring more research in colleges, not only from the direct return of the research data pro-

[2] "Science and Engineering in American Industry," National Science Foundation, NSF 56–16.

[3] Miller, C. L., "A Study of the Private Photogrammetric Mapping Activity in the United States." PHOTOGRAMMETRIC ENGINEERING, Vol. XXIII, No. 1, March 1957.

[4] "Federal Funds for Science," National Science Foundation, NSF 56-19.

PARTICIPATION IN RESEARCH SURVEY

	Government	*Commercial*	*Educational*	*Total*
Questionnaires sent out	10	50*	16	76
Replies received	10	34	10	54
Per cent participation	100%	68%	62%	71%

* 68 questionnaires were sent out based on U. S. sustaining membership of ASP; however, 18 were considered to be inactive in photogrammetry.

duced, but also by making money available to schools that can be used for research assistantships, thus encouraging more students into the profession. It is a means whereby Government and private organizations can show concrete evidence of interest in educating future photogrammetrists. The consensus of opinion, therefore, from educational institutions is that the most serious weakness in photogrammetric research is the lack of such activity in the colleges.

From an efficiency standpoint, several replies stressed the need for greater coordination of effort. The solution to this problem is not readily apparent because of the need by commercial firms to insure financial gain by keeping some of their developments "under wraps" to deny them to their competitors, and because of the requirement for security protection of much of the research done by the Government. Perhaps this is just as well, for while duplication of effort is not to be condoned, coordination of effort tends to breed one-sidedness whereby one organization thrives on the developments of another. The history of United States industry has shown us that competition is a great stimulant to progress.

Another question asked in the survey was "what problems require the greatest attention?" A complete list of all of the answers is attached as an appendix. Research organizations and manufacturers may find this list useful as a guide to future undertakings. The three items that top the list as being those which the profession believes require the greatest attention are:

1. Improvement in the aerial negative to increase quality and resolution.
2. Development of a practical method for analytical aerotriangulation.
3. Automation to eliminate human-operator shortcomings.

Certainly increased resolution will help every phase of photogrammetry, from photo interpretation to analytical aero-

DO YOU THINK THAT PHOTOGRAMMETRIC RESEARCH ACCOMPLISHED IN THE PAST TEN YEARS HAS, IN GENERAL, "PAID OFF?"

	Yes	*No*	*No Ans.*
Government	10	0	0
Commercial	22	0	12
Educational	6	0	4
	38	0	16

DO YOU THINK THAT RESEARCH IN PHOTOGRAMMETRY IS NEEDED?

	Yes	*No*	*No Ans.*
Government	10	0	0
Commercial	23	0	11
Educational	9	0	1
	42	0	12

DO YOU THINK THAT CURRENT RESEARCH EFFORT IN PHOTOGRAMMETRY IS ADEQUATE?

	Yes	*No*	*No Ans.*
Government	2	6	2
Commercial	6	8	20
Educational	0	7	3
	8	21	25

WHAT DO YOU CONSIDER TO BE THE THREE OUTSTANDING DEVELOPMENTS IN PHOTOGRAMMETRY IN THE PAST TEN YEARS?

	Government	*Commercial*	*Educational*	*Total*
1. Kelsh plotter	6	10	5	21
2. "Distortion-free" aerial camera lenses	5	12	3	20
3. Methods for use of convergent photography	4	6	2	12
4. ER-55 proj. (Balplex)	2	7	2	11
5. LogEtronic printer	3	5	2	10

(Quantities indicate number of times each item was listed in first three choices)

triangulation where an entire complicated system of mathematics and electronics is based on the positive identification and position of image points on the photograph. Investigations have shown that there is a loss in resolution of about 50 per cent in pictures taken in the air compared to what the camera-film combination is capable of achieving in the laboratory. There is, therefore, much to be gained from any improvement that research can bring to this long-standing but deplorable condition.

Our philosophy books tell us that "we see through the eyes of the past." With this in mind, a question was posed as to what the profession considers were the three outstanding developments in photogrammetry in the past ten years. Replies included mention of some 20 items, but analysis of the results indicates that the Kelsh plotter is number one. In second place was the development of distortion-free aerial camera lenses, and in third place, the development of methods for the use of convergent photography, followed closely by the development of the ER-55 projector (or Balplex) and the LogEtronic printer.

The selections are easily justified. The Kelsh plotter, because of its simplicity, low cost, and efficient performance, encouraged many individuals and organizations into the photogrammetric mapping field and thus had a great impact on the growth of photogrammetry. The second choice, that of distortion-free aerial-camera lenses, points out the awareness of industry to the importance of the aerial negative. Incidentally, the Geological Survey is proud to have had a hand in the development of four out of the first five selections.

One of the biggest problems that faces all technological industry today is the availability of qualified personnel. An excellent dissertation on the personnel problem in photogrammetry was set forth by Professor Arthur J. McNair in the paper "Education in Photogrammetry" which he presented at the Semi-annual meeting of this Society in October 1956.* He estimates that "at best not more than a half-dozen students with advanced degrees become available to go into the profession of photogrammetry in the United States each year." As mentioned before, one proposed way to correct this situation is to give more research contracts to our schools.

With regard to personnel, the survey revealed that 70 per cent of the Government agencies, 18 per cent of the commercial firms, and 60 per cent of the colleges hire some people primarily for research work. In most cases, an engineering degree is required. Incentivewise, the Government offers challenging work with opportunity to contribute to technological advancement; the colleges offer graduate study; and private industry offers interesting work, and in one instance, "a

* Published in PHOTOGRAMMETRIC ENGINEERING, Vol. XXIII, no. 3.

	Government	*Commercial*	*Educational*	*Total*
Organizations represented	10	34	10	54
Employees in photogrammetric work	2,000	1,300	33	3,333
Retain full-time research staff	7	4	3	14
Do research part-time only	3	17	3	23
Hire personnel primarily for research	7	6	6	19
Amount spent in 1956 on research	$1 million	$270,000	$61,000	$1.3 million
Undertake com. contract work for research	0	15	7	22

California location," an offer which many of us may agree has considerable attraction, particularly after this long winter past. It may be significant that only one Government agency, two commercial firms, and two colleges mentioned salary as an incentive to keep their employees. It would appear that photogrammetric-research people "can't be bought."

Another item of the survey that we shall consider concerns the factors of importance in photogrammetric research. The consensus was that *management* is of number-one importance, with *experience* and *money* running a close second and third respectively. Apparently our profession is aware of the increasing importance of management as a guiding force towards research efficiency. Too often we tend to justify waste and lack of progress with excuses to the effect that research must be allowed complete freedom and that the researcher is some oddity of our society who cannot be managed. Probably the real problem is that some research scientists resent supervision by management with a nonscientific background. The simple answer to this is for the research scientist to participate actively in his own management.

It is interesting to note that in reply to a question as to the availability of research facilities, only three organizations thought to mention qualified personnel. This was undoubtedly an oversight in many cases, but the fact that a valuable contribution to research can be made with personnel alone should not be overlooked. Consider, for example, the possibility of periodically assembling a small group of employees for the express purpose of recording their proposals for the solution of a particular problem. This record can be used in a number of ways. It can be turned over to research organizations, or interested manufacturers, if appropriate. Of course, certain obviously good ideas that will come out of such sessions can be reduced to practice immediately without further research. We might even consider the possibility of forwarding such lists to the Research Committee of the Society for dissemination to the membership in accordance with some prearranged plan. Such "brainstorming" sessions, as they are called, are usually composed of from five to ten people picked at random from all levels within the organization.

The main point to remember is not to exclude any ideas, no matter how ridiculous. The "crazy" idea may be the spark that sets off a lot of bang-up ideas just like a string of firecrackers. These sessions are becoming common practice in many progressive organizations today with reportedly great success. They serve to develop "creative thinking," a factor extremely vital to research. Much good literature[5] is available on this subject, hence it shall not be pursued further in this paper. Suffice to say that *all* photogrammetric organizations have the facilities for research—the brains of their employees. "Brainstroming" is an inexpensive but fruitful means of utilizing these facilities.

Thus, in summary, the research survey has revealed that—

1. We should spend more money on photogrammetric research.
2. We need to give more research contracts to our educational institutions.
3. The number-one item to work on is improvement in the resolution and quality of the aerial negative.
4. That the Kelsh plotter is considered to be the outstanding development in photogrammetry in the past ten years, and
5. That *management* is the most important factor in photogrammetric research.

It is realized that some of the data derived from the survey is debatable. It is further recognized that any one of the items touched upon could be the subject of a complete paper or even a symposium. Nevertheless, an attempt was made to present an over-all picture of photogrammetric research to stimulate thinking and future planning on the subject.

Appendix

Research Problems in Photogrammetry that Require Greatest Attention in the Opinion of Photogrammetric Organizations Contacted in Research Survey

GOVERNMENT

1. Quality of photography; reduction of control costs; improved instrumentation and techniques.

[5] Osborn, Alex F., "Applied Imagination," Charles Scribner's Sons, 1953.

Thomas, Charles Allen, "Creativity in Science," Arthur D. Little Memorial Lecture, Massachusetts Institute of Technology, April 1955.

2. Greater resolution in aerial film or new type of camera suited to control extension with electronic computers.
3. High-altitude mapping photography.
4. Adequate means of handling color photography for measurement and map compilation purposes in connection with geologic work.
5. Analytical photogrammetry; automation of stereocompilation; electronic elevation determination from the airplane.
6. Improving of data recording media (film, paper, etc.) e.g. higher resolution and greater stability; improve methods, measuring instruments, and electronic computers for analytical aerial radial and spatial triangulation; automation in general.
7. Hiring and keeping competent personnel; stabilizing aircraft cameras; increasing resolution of camera optical systems; electronic storage of photogrammetric and geodetic data so that maps at any scale can be produced automatically.
8. Application of photogrammetry to highway engineering problems and coordination with electronic methods of computation; large scale (100′ to 1″ or larger) topographic mapping; cross-section and profile measuring.
9. Speeding-up process of compiling maps; accurate extension of control from data obtained by primarily airborne means.

EDUCATIONAL

1. Civil engineering and non-topographic problems such as large-scale mapping for highway engineering and investigations in the fields of structure, hydraulics, medicine, and physics.
2. More practical application in the highway field.
3. Application of electronic calculators to analytical, instrumental, and graphical problems.
4. Joining together of electronics and photogrammetry. New instruments of low initial cost for large-scale mapping (20 to 50 feet per inch).
5. Better textbooks, demonstration equipment, and training aids for photogrammetric courses.
6. Aerial triangulation, both instrumental and analytical, tilt-free photography, image-motion compensation; stable film base.
7. Automatic contour plotting, analytical aerotriangulation and adjustment of strips and blocks.
8. Systematic evaluation of over-all "photo reconnaissance—photo use" process to determine which factors most limit the amount of information derivable from aerial photos; development of practical methods of measuring plate coordinates for use in analytical investigations of data compilation, control extension, strip adjustment, etc.

COMMERCIAL

1. Improvement of negative quality; stabilizing and improving aircraft and camera performance (twin-engine aircraft plust faster shutters equals flatter models).
2. Automation applied to data reduction.
3. Camera stabilization; aerial film speed.
4. Stereotemplets and *C*-factors.
5. Large-scale highway mapping.
6. Anything leading toward simplicity instead of increased compilation.
7. Minimizing control, radar photography, better materials.
8. In the field of special applications and measurements.
9. Improved viewing equipment.
10. Equipment to do work of remembering and automatically performing duties in order to reduce losses encountered by operator fatigue or normal human shortcomings.
11. Improved instrumentation for mapping, photo interpretation, and aerial triangulation.
12. Improvement of map accuracy by increase in resolution; reduction of plotting-instrument complexity by verticality control.
13. Proper systems management of the research effort to assure benefits to the entire field.
14. More efficient and less expensive instruments; for 99 per cent of work, so-called third-order instruments are sufficient.