Heft 2

München, Juli 1978

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Standards and Specifications for Integrated Surveying and Mapping Systems

Workshop held in Munich,
Federal Republic of Germany
1–2 June 1977

Editors: A. Chrzanowski and E. Dorrer
assisted by J. McLaughlin

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A C K N O W L E D G E M E N T S

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F O R E W O R D

The Workshop on Standards and Specifications for Integrated Surveying and Mapping Systems was held at the University of the German Federal Armed Forces (Hochschule der Bundeswehr) in Munich on June 1st and 2nd, 1977. The Department of Civil Engineering and Surveying at the University, together with the Working Group on Computational Photogrammetry of the German Society of Photogrammetry and Remote Sensing and the Department of Surveying Engineering of the University of New Brunswick (Canada), served as sponsors.

The purpose of the workshop was to provide an informal forum for the review of integrated survey pilot projects under development in several different countries and to consider some of the more pressing issues which must be resolved before such projects may be commissioned for ongoing routine operation. The organizers intended that the workshop deliberations would be conducted in the form of semiformal panel discussions coupled with contributions from the floor. Because of the background and interests of the forty-four delegates from nine countries who participated in the workshop, particular attention was given to the preparation of effective standards and specifications for integrated surveying and mapping systems.

The development of integrated surveying and mapping programs as the positional foundation for land information systems has become a topic of significant importance in recent years. Efforts to date have largely focused on the hard technology associated with systems design: surveying and photogrammetric technology, computer and data management technology, cartographic engineering, etc. Increasing attention, however, is being given to a number of interdisciplinary concerns such as the socio-economic need for modern spatially referenced information systems, the economic-legal-technical criteria to be employed in systems standards and specifications, information management criteria, etc.

It is the hope of the organizers that the workshop may contribute to the formation of an international working group, perhaps under the aegis of FIG Commission V, to examine in detail the various technical, socio-economic and legal problems associated with developing and administering integrated surveying and mapping systems.

T A B L E OF C O N T E N T S

OPENING REMARKS

by

EGON DORRER, Hochschule der Bundeswehr München, Germany
ADAM CHRZANOWSKI, University of New Brunswick, Canada
RON ADLER, Chairman of Commission V of F.I.G.

OPENING REMARKS

Dorrer

It is an honor and great pleasure for me to welcome you at this workshop. You are coming from different parts of the world, from different countries, and this shows an interest in the topic of the workshop.

Some of you might be surprised why this workshop has been organized at this university, the University of the Federal Armed Forces. It is purely coincidental and truly speaking this workshop has nothing to do with the armed forces. It has just happened that we have had the honor of having with us Dr. Adam Chrzanowski of the University of New Brunswick who has joined our staff as a visiting professor for about five months. He has been involved in works and problems of integrated surveying and mapping systems for a few years. After numerous discussions on the topic we have decided, just the two of us, to organize this meeting. Myself, as chairman of a working group on computational photogrammetry of the German Society of Photogrammetry and Remote Sensing had, in any event, been planning a meeting of our group for months. I thought that it would be a good idea to organize it now, while Dr. Chrzanowski is still with us, in order to combine the discussions on computational photogrammetry with the more general problems of integrated survey systems. Our working group on computational photogrammetry is very much interested in applying its findings in practical problems, particularly in the field of block adjustment and analytical aerotriangulation.

It is not quite clear how to define the term: Integrated Surveying and Mapping System. One of the purposes of this workshop is to establish the definition. According to my understanding, integrated systems should create a basis for positional information systems which are so important in land management, in multipurpose cadastre, in infrastructure cadastre and in environmental monitoring, just to mention a few uses. The surveying profession can and must provide the positional data basis. Whether it should be in a graphical or digital form will be discussed during this workshop.

Numerous pilot projects on integrated survey systems have been conducted or are being planned in number of countries under the auspices of governmental agencies, surveying offices, research institutes, etc., etc. There is an obvious lack of coordination and exchange of information between those projects. Need for some sort of technical standards and specifications for integrated survey systems has been expressed by a number of persons who are involved in the establishment of integrated systems. For these reasons, this workshop is supposed to answer the question whether or not an international working group should be created, which then would be taking care to develop guidelines for standards and specifications for integrated systems. It seems that Commission V of F.I.G. is ready to serve as an umbrella for such a group. Since we have with us Dr. Adler, Chairman of this Commission V, he undoubtedly would like to say something in this respect. From my point of view, it is also an important point to say that existing international professional groups or organizations such as F.I.G., I.S.P. or I.C.A., generally feel that many overlapping regions and areas do exist, and that a closer cooperation is necessary between these organizations. Perhaps this workshop will be able to start at least some sort of closer and tighter cooperation.

I hope that the meeting, despite its heterogeneous character and despite or because of its informal character, will through some light on some of the questions listed in the program.

All the presentations and all discussions and remarks will be recorded on audio tapes. We shall try to transcribe the tapes immediately after the workshop, and after some reviewing and editing we hope to publish proceedings of this workshop. This will take some time, perhaps several months.

Well, I would like now to ask Dr. Adam Chrzanowski, the coorganizer of this workshop to give his opening remarks.

Chrzanowski

I will try to make my introductory remarks as brief as possible. I am representing the University of New Brunswick and a study group on the development of standards and specifications for integrated survey systems in Canada. Our group at UNB was organized about five years ago after the second Canadian conference on integrated survey systems for urban areas which took place in Ottawa in 1972. One of the main conclusions of the national conference was that we should investigate how the existing standards and specifications for survey activities should be adapted to new approaches needed in the development of integrated survey systems. I know that not everybody understands exactly what we mean by the term "Integrated Survey systems". We have discussed in a smaller group, just an hour ago that we should use instead maybe a term "Correlated Surveying System" or replace it even by some other expressions. I hope that this basic question will be answered in the first session of this workshop.

I am very grateful to the Hochschule der Bundeswehr for allowing us to use their facilities for organizing this workshop. Dr. Dorrer has already explained clearly the purpose and goal of our workshop. I would like to add only that as a part of our research program at the University of New Brunswick, we have investigated different approaches in different countries towards the development of integrated survey systems, and we have concluded that there is a lot of overlapping work being done in different countries. Many countries are trying to organize some kind of pilot projects directed towards the development of integrated survey systems. Many photogrammetric projects are pursuing similar topics, and similar conclusions are drawn. It indicates that there is a lack of coordination of this type of work and a lack of exchange of information. Therefore, we came to the conclusion that it would be a good idea to organize an international study group which would take over the task of coordinating the research in the field of the development of integrated survey systems and to act as an information centre on the projects being carried out in different countries. Thus, everyone who would be interested in this type of research would be able to contact one central office from which he could gather all the information concerned with what is going on in the different countries. Last year, I contacted Dr. Ron Adler, who is the chairman of Commission V of F.I.G., asking him whether Commission V could act as an umbrella for such an international study group. Commission V is involved in new instruments and new methods in surveying.

Since integrated surveying systems require the development of new measuring, computational and technological systems, I feel that Commission V would be a proper "home" for this type of an international study group. Our workshop is to conclude whether there is really a need for such an international study group, and what should be its terms of reference. In case such a group should be created, then Dr. Adler, when going to Stockholm next week, could present our conclusions to the General Assembly of F.I.G..

Now I would like to ask Dr. Adler, as the chairman of Commission V, to give his opinion about the organization of such a group. Dr. Adler will be moderator of the first session.

Adler

Perhaps we should get very quickly into the first session since we are running behind time. I would like to open the session with a few words about the general philosophy of this meeting.

I was very happy to accept the invitation of Professors Dorrer and Chrzanowski to participate in this meeting. The concept of integrated surveys is something which we are all talking about, but I don't know if we really have a common understanding as to what it means. The concept of integrated surveys in Europe, where much surveying activity has occurred (some would even suggest: where everything has been done), is much different from that in North America where there is no tradition of surveying and mapping, and where there are vast areas to be surveyed. In this developing or emergencing countries some of these ideas are nonspecific and often abstract, yet these are the countries which will be concerned with the integrated survey approach from the outset of their development. Therefore, international gatherings such as this meeting must take into consideration very different perspectives.

Another misgiving I have is whether there is a two way flow of ideas between the academics creating these systems and the users of the systems. I feel that there is no other way to go about this process except to let the academics develop the systems and present them to the users. However, there remains the question as to whether there is a Feedback of ideas.

One more misgiving is whether there can be a discussion of universal standards and specifications, or whether we can only indicate approaches to be taken on an individual basis, to be adopted by each country for its own state of affairs. I think it would be very dangerous to create an international standard for control networks, to cite one example, where Western European requirements may be inapplicable in North America, Africa or Asia.

Having voiced so many misgivings, I would like to say that I am not all that pessimistic. I think that we should have a very good meeting, with an emphasis on discussion and clarification and only limited formal presentations. If we should decide to recommend the creation of an international working group under Commission V of F.I.G. in tomorrow's conclusions, I will make this proposal in Stockholm. F.I.G. would appear to be a suitable organization for such a purpose, inasmuch as it is an organization of practicing surveyors. Whatever we create within the academic world, and in meetings such as this, other people have to swallow the ideas and try to put them into practice. I feel that F.I.G. would be a good platform for this purpose.

SESSION I

NEED FOR INTEGRATED SURVEY SYSTEMS

Moderator	R. Adler (Israel)
Panelists	G. Konecny (Germany J. McLaughlin (Canada) U. Van Twembeke (Belgium)
Discussants	F. Ackermann (Germany) F. Au (Germany) J. Clapp (U.S.A.) K. Barwinski (Germany) B. Dubuisson (France) H. Andris (Switzerland)

This session dealt with the following issues:

(1) What is the purpose of an integrated survey system?

(2) What are the needs of a multi-purpose land cadastre system?

(3) Graphical vs. numerical information system?

S E S S I O N I

Adler

I would like to open first session with a discussion of the question, <u>what is the purpose of an integrated system?</u> Perhaps I could most appropriately begin by giving a description of an "unintegrated survey system". Please note this photograph (Fig. 1-1) of an area just north of Tel-Aviv. The photograph was taken around 1947 and, as you can see, this area is completely empty. In fact it was used for agricultural purpose.

This agricultural land was subdivided into a series of blocks as a result of a cadastral survey based upon the limited topographical features of the area. Traverses of a control network, as represented by the circles for traverse points, may be seen on the photography. The cadastral survey was valid for only a few years when a major development was proposed (Fig. 1-2). It is very difficult to correlate the planning sketch used for the development proposal with the original cadastral survey and aerial photograph of the area. In fact we have a second survey which was to provide the basis for the development and subdivision of the land.

The proposed development became a reality in 1962, if I'm not mistaken, and the land was subsequently fully developed. There are certain discrepancies between the planning proposal and the actual execution which can be seen on a third photograph (Fig. 1-3). This aerial photograph could be regarded as a third survey. Finally there is a cadastral plan of the developed area which can be considered the final product.

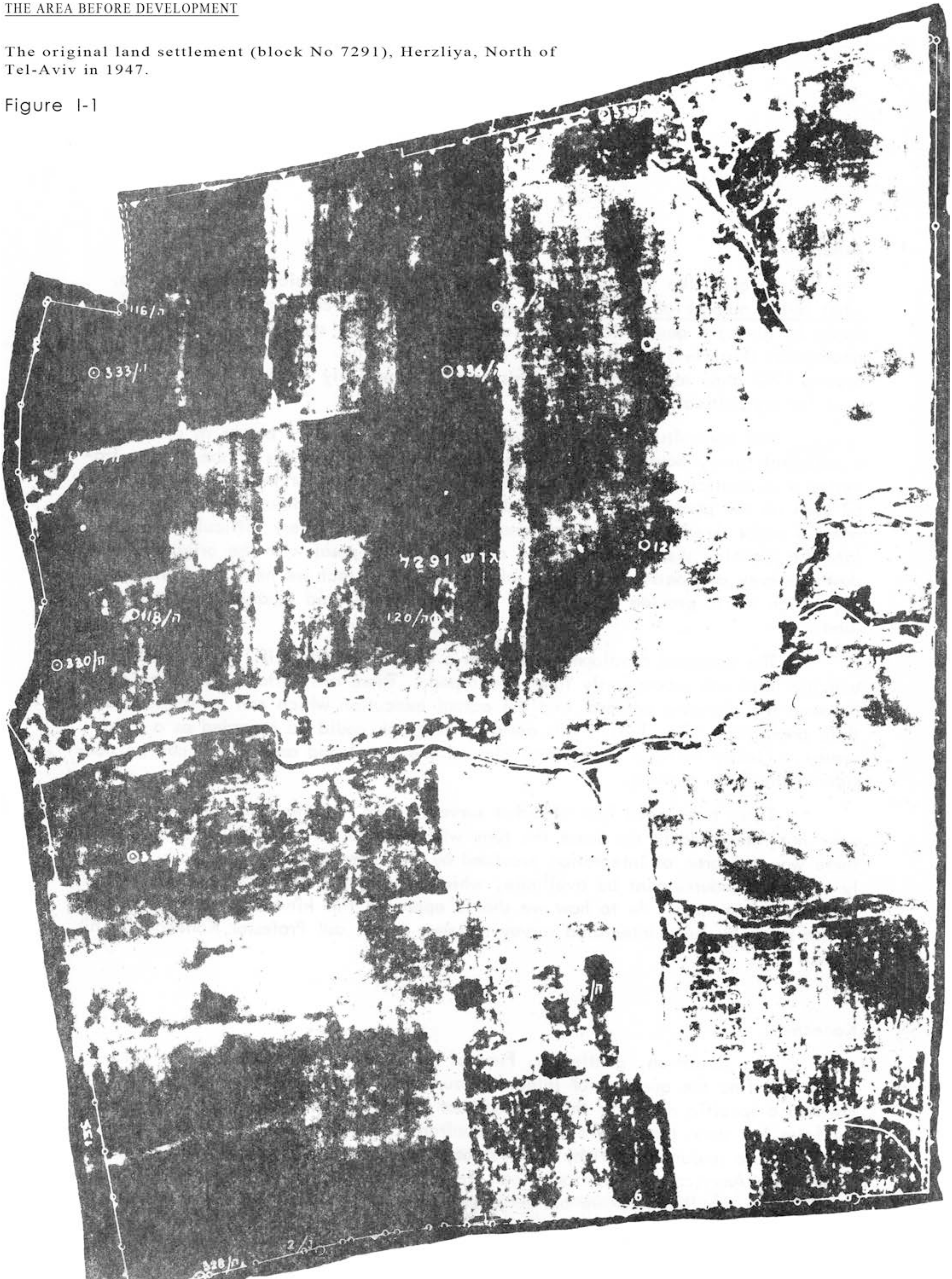
There have been four different surveys, then, of this one land area which were not integrated in the sense the term will be used during this workshop, although there was a degree of integration provided by the common control network. Obviously better procedures must be available, which will save a lot of professional effort and a lot of money. As to how we should approach this kind of problem, and what do we mean by fully integrated survey systems, I will ask Professor Konecny for his views.

Konecny

Mr. Chairman, gentlemen. First of all I should point out that we Europeans will find the question of integrated surveys a little bit startling. We have not had a specific name for this concept but rather, as Dr. Adler just mentioned, we have just done them. We are now confronted with the wish expressed internationally to give reasons as to why surveys should be integrated, and we always hear from North America the question, "can we justify our authority to do integrated surveys?" For the first time we are realizing that we in Europe have been reading ancient periodicals, that we do not know the reasons. We simply do integrated surveys because we have always done them.

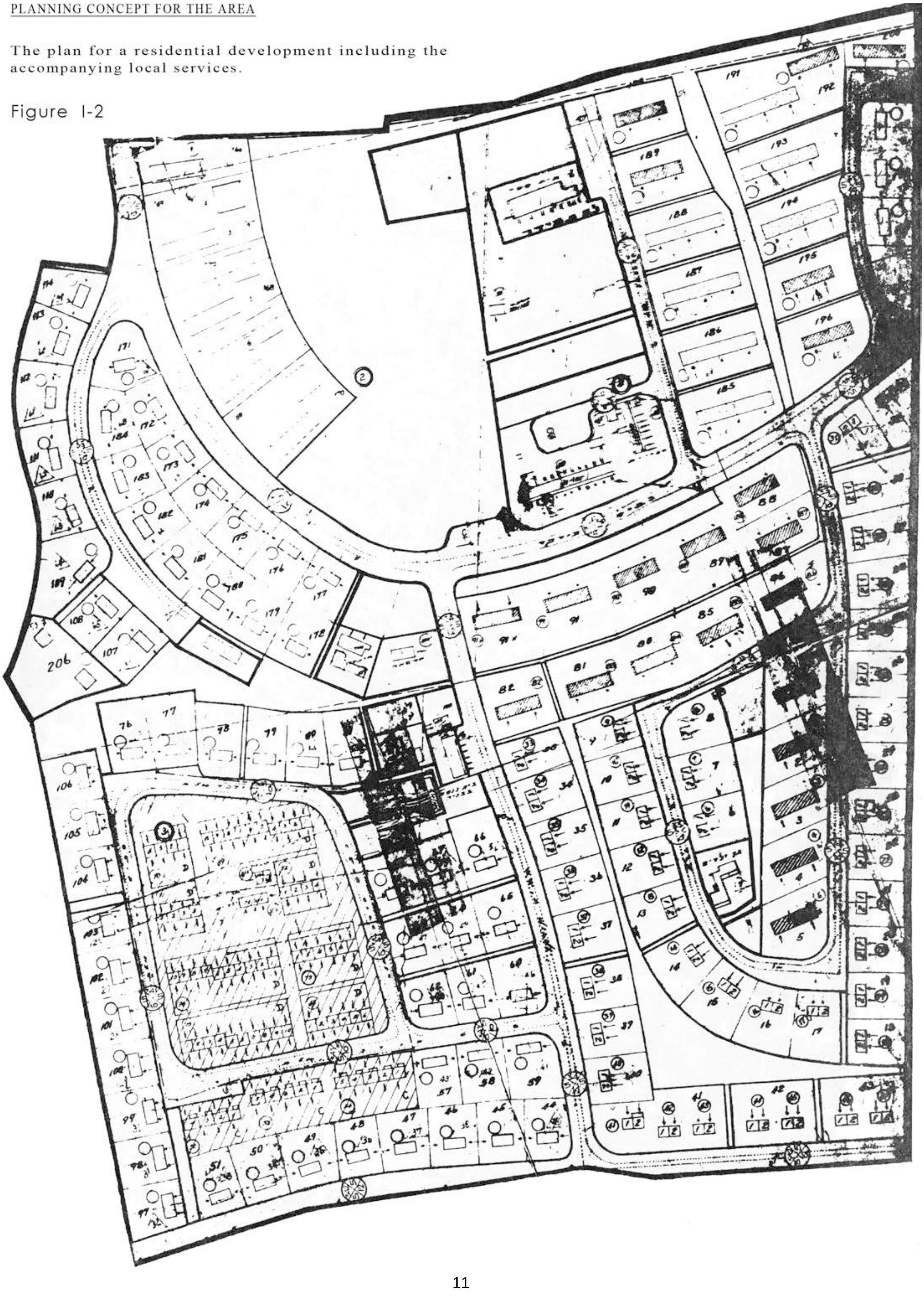
The original land settlement (block No 7291), Herzliya, North of Tel-Aviv in 1947.

Figure I-1



The plan for a residential development including the accompanying local services.

Figure I-2

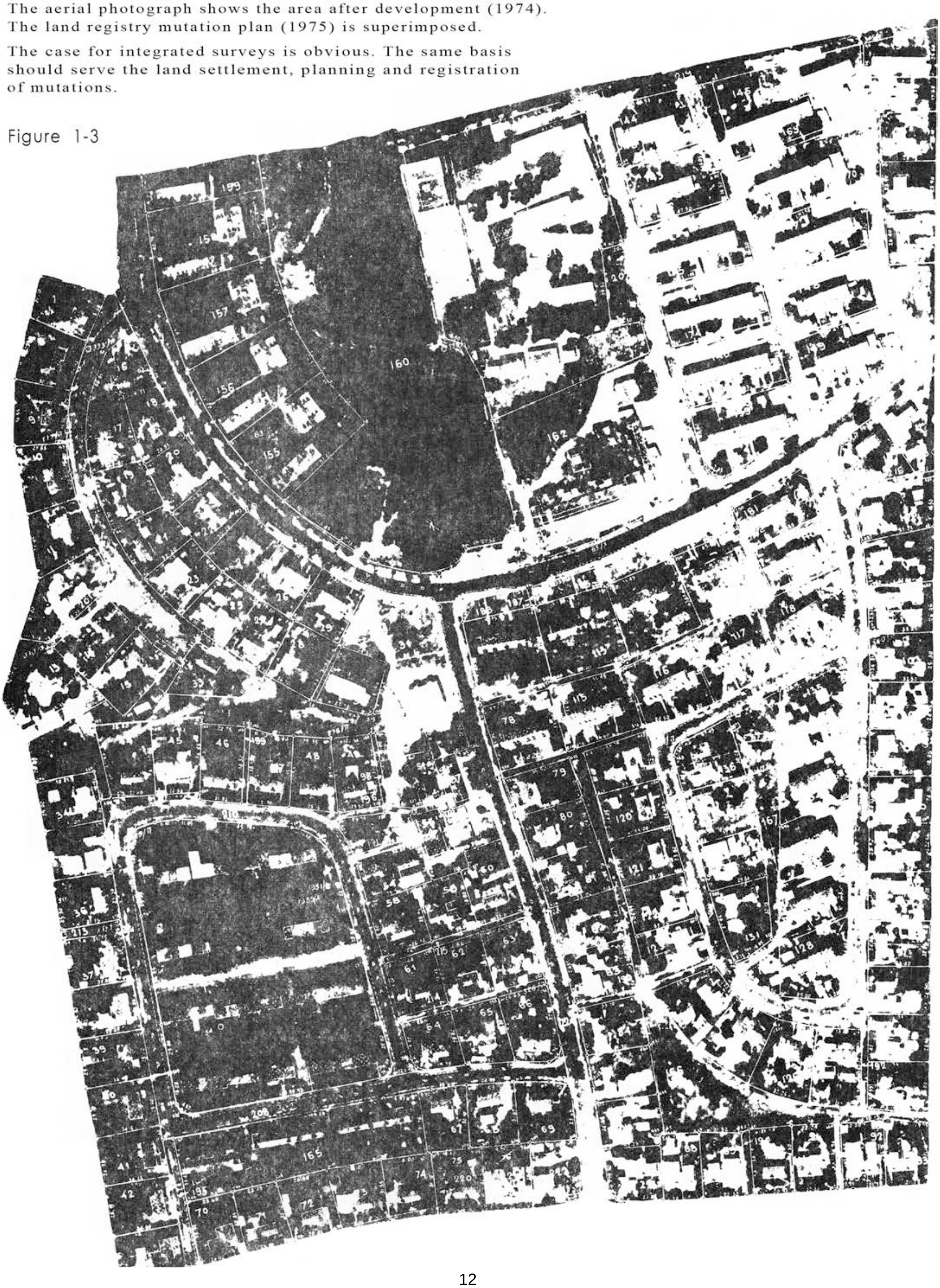


THE AREA AFTER DEVELOPMENT

The aerial photograph shows the area after development (1974). The land registry mutation plan (1975) is superimposed.

The case for integrated surveys is obvious. The same basis should serve the land settlement, planning and registration of mutations.

Figure 1-3



I think it is a useful occupation for us to think about this integrated survey concept as well from other perspectives. In this age of automation, we Europeans have a responsibility to rethink our present procedures in order to make them more suitable for automation. As well, some of us are also engaged in providing advice to developing countries, and we need to have an eye on their problems.

As the German Benzenberg noted nearly two hundred years ago, "in connection with the cadastre, it is most important that one makes every effort to finish it." We do not have anyone who can wait two hundred years to have an integrated survey system completed, so let me turn back to the basic question as to what is an integrated survey system. I will attempt in a few words to give my understanding of the concept. There may be other definitions.

I think that an integrated survey system is one where surveys are carried out by various agencies, including government departments, industry and private surveyors. All of these surveys are referenced to each other or, as Dr. Chrzanowski said, correlated to each other. I think that this idea of referencing the surveys to each other is the basic idea.

In Europe we have also found that a second prerequisite is the maintenance of a monumented survey or control system. It is quite clear that such a monumented control system cannot be maintained by one user alone. Rather government must instruct an agency to maintain such a system for the benefit of all.

One of the obvious benefits to be derived from integrated surveys is that one of course can obtain maps from existing surveys without actually performing any new mapping. Perhaps this will have to be done the first time, but not in subsequent iterations. In order to provide for this, legal measures must be introduced to require that surveys are performed in an integrated manner – and of course they must be coupled with some enforcement measure. So there must be an agency which enforces the legal regulations. Any survey must be performed accordingly and must necessarily be reported to this agency.

Let me now try to explain the purpose of an integrated survey system. Probably the most important purpose is to avoid duplication, a problem which Dr. Adler has described with his four different surveys example. This is a waste of funds and of time. All efforts should be directed towards eliminating duplication. This applies to the different types of surveys; e.g. industrial surveys may use the control of engineering surveys in order to only have to measure small distances rather than having to begin with transferring control from far away. The second purpose is to provide an up-to-date mapping system. There is no way a mapping system can be kept current except by recording changes in an organized manner. I think efforts have been made in North America on several occasions to map cities at intervals of five to ten years in a fashion that only benefited the companies doing the job. These are the significant purposes for such a system.

I would also like to consider the constituent elements in an integrated survey (Fig. I-4), although we have basically mentioned them already. We must consider topography, property surveys (in Europe this would be part of what we would call a multi-purpose cadastre), utility surveys, etc. Topographic surveys would include roads, buildings, elevations, vegetation and water. Much of this information can be effectively compiled photogrammetrically, although some information (such as legal and subsurface utility information) will require ground surveys, e.g. the survey of power lines, water lines, sewerage, gas lines.

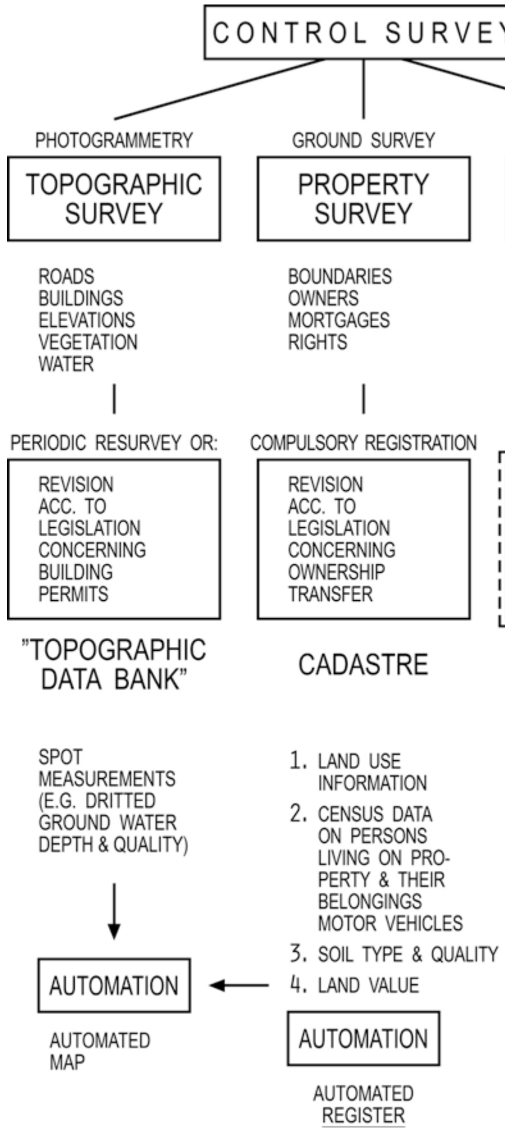


Figure I-4. Constituents of an integrated survey system

Integrated surveying requires a close dialogue between the photogrammetrist and the field surveyor, using the reference control network as a common language. We must also consider the problems of revision, particularly those changes of a legal nature. For example, from a legal standpoint purchased land is really not transferred to the new owner unless his parcel is registered. Cadastral registration in Europe serves as a protector. There could be similar measures, e.g. for reporting of constructions, or utilities as Dr. Van Twembeke has cited, which might be treated similarly.

A vehicle such as the cadastre could be used to carry additional information, stored in and manipulated by some huge data bank.

I would like to conclude my remarks at this point.

Adler

Thank you very much, Dr. Konecny. I think that I have already managed to write down some rough definitions of what an integrated system is, from Dr. Konecny's words. Dr. McLaughlin, would you like to make any additions at this point?

McLaughlin

Thank you, Mr. Chairman. My charge today is to briefly describe to you the situation in North America, to give you some insight into the North American perspective on these matters. It may not be a surprise to learn that what I have to say is really just reinforcing what Dr. Konecny said. The concept of an integrated survey system in North America, and particularly in Canada, evolved in the 1960's, a period during which Dr. Konecny was very active in Canada. I would suggest that he had a tremendous influence on the ideas that developed in North America, and probably to a certain extent has been influenced in return. I would like to keep my remarks at this stage fairly brief, starting by pointing out to you that while North America may seem in many ways to be a homogeneous society with one dominant language and culture, in fact when you take about survey problems, when you talk about problems dealing with land, land tenure and land administration, really you are talking about problems that are constitutionally delegated to either the state in the United States or the province in Canada. We are looking at a heterogeneous system in North America, and it is not possible for me to give you a collective North American viewpoint. In fact, there are many points of view, with many different ideas being pursued. What I will do is suggest some of the more progressive movements which are taking place.

The concept of an integrated survey system is somewhat ambiguous, particularly, if you recall that I.T.C. has apparently developed a concept which is quite a bit different from that which Dr. Konecny has presented. In North America the concept has come to mean essentially what Dr. Konecny is talking about: a system of survey in which there is a common spacial referencing framework upon which are integrated the various types of public and private surveys (photogrammetric base mapping, cadastral surveys, engineering surveys, utility surveys, etc.). These surveys are further integrated in the sense that there is a common examination process and a common process for recording the spatial information generated.

The Land Registration and Information Service of the Maritime Provinces of Canada may be cited for illustrative purposes. This program is now approximately fifteen years old, and is providing a common survey framework for three Canadian provinces. The system is being built for a fairly small population of about two and one half million people, utilizing about one and a half million cadastral parcels. Within this region there is now a common spacial referencing system based upon a plane coordinate framework, and a unified series of topographic base maps. The whole operation is managed by one survey department. In one sense this is very much an integrated survey system, inasmuch as there is one dominate survey organization responsible for the control, mapping, and for examining and recording other surveys. While this approach is currently being employed only in one small part of Canada, somewhat similar ideas are coming into play and somewhat similar systems are evolving in other parts of North America.

It is important to appreciate the truly significant differences between European and North American societies. For example, the long and highly respected European treatment of surveying is almost unknown in North America. Instead, North Americans have tended to be concerned with those technologies useful to extensive, macroscopic developments. Given our large land mass and small population base, this is perhaps not surprising. Gradually the emphasis is changing, however, as more intensive land practices come into vogue, scarcities appear on the horizon, and land values begin to rise quite dramatically. Not surprising perhaps, this is resulting in a fresh, new interest in surveying. On the other hand, because of the lack of a long tradition, there is the ideological freedom in North America to design the most optimal surveying systems possible, provided only that such concepts are subjected to rigorous economic scrutiny. It is not possible for a survey organization to obtain money in Canada or in the United States, unless it can demonstrate significant benefit to cost ratios. These concerns will be reinforced tomorrow in our discussions on standards.

Let me conclude at this point by stating that the North American concept of an integrated survey system is substantially that put forth by Dr. Konecny and that the significant problems we are encountering with such systems are not of a technical nature, but rather are of a socio-economic and institutional perspective.

Adler

Thank you very much, John. Professor Van Twembeke, would you like to continue with this first question?

Van Twembeke

At present a joint effort of research institutes, map makers and map-users is concentrated on developing economical techniques for the preparation of integrated large scale maps in graphical or graphic-numerical form.

In developed countries, small-scale and medium-scale topographic maps are usually available. Large-scale maps are often also available but large-scale mapping up to now has been inspired only by the application of land taxation and the delimitation of the property. These cadastre maps present a real interest but they are not utilizable in the case of specific problems.

At present we need maps for intensified planning purposes, new technical projects, agricultural operations, urbanism and cadastre. The elaboration of these multi-purpose maps requires high investment and amortization costs.

The situation is entirely different in developing countries. No medium-scale topographic maps and no geodetic and topographic points are available. These countries consequently cannot solve the problem of integrated multi-purpose maps by copying the procedures proposed in the highly developed countries.

At present the geometric, technical and administrative information in keeping up with the occupation of the ground and the underground is managed by a number of official, semi-official or private societies or companies; lack of coordination gives rise to comments and useless repetition of surveys, mapping and execution of public works. This situation has reached an alarming level because:

– The available space is diminishing every day (parking zones, the underground railway, ...).
– The investments in ground and underground are stretching themselves about several generations of technicians passing away with their techniques, surveys, maps and reference marks.

In order to cure this evil we have to centralize the
(1) existing information
(2) management of this information
(3) diffusion of this information.

The lack of integration can be calculated. In 1976 a realistic estimation was made for the city of Brussels:
a) Companies trenched about 2000 m every day at 20 dollars per meter. A centralization of the planning and decision-making can save 15% of the money spent: cost: 1.3 million dollars.
b) Research departments. In 1976, 250 million dollars was spent for public works. The royalties are calculated at 5% and 12% of the time lost by collecting dispersed information. Cost: 1.5 million dollars.
c) Department of Public Works. Failure to appreciate the underground network causes destruction of pipelines and cables and affects the basic price by 2%. Cost: 5 million dollars.

This evaluation proves the necessity of an integrated survey system and shows the economic interest of this system. The purpose of an integrated system can be briefly described as follows:
– A better organization of the works in rural and urban zones.
– A simplification of the studies made by private and public offices including the suppression of many overlapping ground surveys.
– The decrease of incidental expenses required by the contractors when they execute unexpected works in the underground.
– To make the best use of all forms of information available.
– To ensure flexibility and expansion capability in order to meet changing user needs.

On account of the high technical level of automation, the rapidly rising demand of different branches of the national economy, and the high investment and amortization costs, the final solution of our problem is to be reached in two phases:
First phase: Elaboration of a large scale map presented in a new integrated form.
Second phase: Elaboration of a graphic-numerical management system providing improved knowledge of land resources.

The graphic-numerical form will probably be the final product allowing wide application of automation in elaboration of graphical and numerical cadastre and engineering maps, and providing a new set of statistics for use in analyses and planning.

However, in specific cases for European countries with a Napoleonian fiscal cadastre, or in developing countries, the graphical integrated land information system can be sufficient. The very attractive numerical "databank information system" cannot be justified economically in all cases.

Another point is that a numerisation or digitisation process requires maps in an appropriate form. An annotated intermediate photomap with its appendices can serve very adequately our purpose. The objective of the proposed method is the plotting of thematic line maps from orthophotographs or stereoorthophotographs.

Adler

Thank you, Professor Van Twembeke. Gentlemen, do we have any questions from the floor on the first topic which is: "What is the purpose of an integrated survey system?" Are there any remarks or questions from the floor? Yes, Professor Ackermann.

Ackermann

Perhaps I should briefly mention the I.T.C. concept of integrated surveys, just as a matter of contrast. The I.T.C. concept of integrated surveys is very different from what has been said here. It refers to the various surveys and their integration which are needed for political and economic decision making, be it on the level of state or regional organizations or of municipalities. The term "survey" is used in a very general way. Whenever political, economical, or technical decisions have to be made, then various environmental and other information have to be brought together in order to be properly and adequately considered. Especially their interrelations have to be taken into account before decisions are made which will concern everybody. That concept of integrated surveys implies much more than just referring surveys of more or less conventional nature to a common reference system.

Au

I assume there are some difficulties with the definition of integrated surveys. Reading the programme of the workshop the title should be integrated Surveying and Mapping Systems and until now we are talking only about the surveying system. Are these two different systems or only one?

Adler

Well, it appears to me that we are talking about both, perhaps it appeared that we are talking about only surveying, but we are really talking about both surveying and mapping.

McLaughlin

In Canada, mapping is part of surveying and surveying is a very broad term.

Adler

Well, gentlemen, on this first question we have tried to define what an integrated survey system is and using Professor Konecny's definition I have written down that integrated surveys are surveys that are carried out by different agencies, referenced to each other, brought into common denominator by a coordinated control system, and which permit the production of an up-to-date map for the purposes of topographic surveys which include various development purposes, property surveys, and utility surveys. And if we wanted to include an addition on the lines expressed by Professor Ackermann, this would certainly broaden the scope of the survey. But I think that we are already a little behind the time, so, let's turn to question number two: "What are the needs of a multipurpose land cadastre system?" And now I have to ask all the speakers to be as brief as possible.

Konecny

As we have seen a cadastre consists of at least two things: a register and a property map. I think when we talk of a cadastre today, however, that we should widen this concept. We should say that a cadastre consists of monumented boundary points, of numerical survey records, of a cadastral map, of a register of legal rights, of a register to show such properties of a parcel as land use, etc. – all the prerequisites for a geographical data bank.

In reviewing the historical development of the cadastre in Europe, e.g. in Germany (Fig. I-5), we will note that before 1900 they were established as tax cadastre. They consisted primarily of tax maps which referenced parcels and were used to determine areas for taxation purposes. In the United States tax cadastral mapping is also now important.

1. TAX CADASTRE BEFORE 1900

A. TAX MAP TO REFERENCE PARCEL & TO DETERMINE ITS AREA

B. REGISTER TO SHOW PARCEL OWNERS TO BE TAXED

2. OWNERSHIP PROTECTION CADASTRE 1900-1920

A. NUMERICAL SURVEY RECORD TO REESTABLISH A.
TO SHOW MEASURED DATA

B. MONUMENTATION OF BOUNDARIES MAIN PURPOSE

C. MAP AS GRAPHICAL RECORD OF A. (OR IN PLACE OF A.)

D. REGISTER TO SHOW PARCELS OWNERS;
MORTGAGES & RIGHTS

3. MULTIPURPOSE PLANNING CADASTRE AFTER 1920

A. NUMERICAL SURVEY RECORD ON COORDINATE BASE

B. MONUMENTATION OF BOUNDARIES

C. MAP AS GRAPHICAL RECORD

D. REGISTER TO SHOW PARCELS OWNERS;
MORTGAGES & RIGHTS AND OTHER PROPERTIES
ASSOCIATED WITH AREAS
(E.G. LANDUSE, BUILDINGS)

Figure I-5. Development of the Cadastre in Germany.

The next step was to focus on the cadastre in terms of its role in protecting land ownership. In this case emphasis was placed on the actual monument which was to be reestablished – a very expensive procedure introduced here in the 1920's. Legislation was enacted providing for graphical, or more often, numerical survey record. Of course this was then used as a map, and again one had the register.

Today we think of the cadastre essentially as a multi-purpose planning system – the only area where we can clearly justify the establishment of such systems. The previous function of the cadastre would eventually be a question for the owner to obtain protection of his rights. Much more important, however, are public rights, particularly when related to planning. The multi-purpose planning cadastre system will consist of a numerical survey record based on coordinates, of unmonumented boundaries – there will perhaps arise some discussion on that – of the map, and of the register containing as many things as are necessary for planning.

Of course the requirements will be quite different in different parts of the world. In a pre-industrial economy (Fig. I-6), where the G.N.P. per capita may be less than 500 dollars per year, the societal requirement may only extend to a small scale mapping for transportation purpose, etc. If one establishes a cadastre in such a society, it may be something of a luxury. This is actually, quite prematurely, how our cadastral systems in Europe were established.

In an industrial environment, with a per capita G.N.P. in the order of 3000 dollars per annum, there will be a need for products such as 1:50,000 mapping for planning natural resource developments, etc. Larger scale surveys will only be required for construction purposes, or where specific requirements of property owners must be met.

TYPE OF ECONOMY	G.N.P. PER INHABITANT U.S. S/YR.	PREDOMINANT PRODUCTION TYPE	NECESSITY FOR MAPPING	
			SMALL SCALE	LARGE SCALE
PRE-INDUSTRIAL	50 TO 500	AGRICULTURE	TRANSPORT 1:250 000 (DEFENCE 1: 50 000)	(TAX CADASTRE WHERE DESIRED)
INDUSTRIAL	500 TO 3 000	CONSUMER GOODS	PLANNING OF NATURAL RESOURCES 1: 50 000	CONSTRUCTION (PROPERTY PROTECTION WHERE DESIRED)
POST-INDUSTRIAL	OVER 3 000	SERVICES	DERIVED FROM LARGE SCALE MAPS	PLANNING AND MANAGEMENT OF NATURAL AND HUMAN RESOURCES 1: 5 000

Figure I-6. Types of economy and need for mapping.

In the densely populated, post-industrial societies, there is a crying need for a planning and management system of human and natural resources which will require mapping at the scale 1:5000. At this stage, the mapping requirement will be coupled with the multi-purpose cadastre concept. Figure I-7 showing different

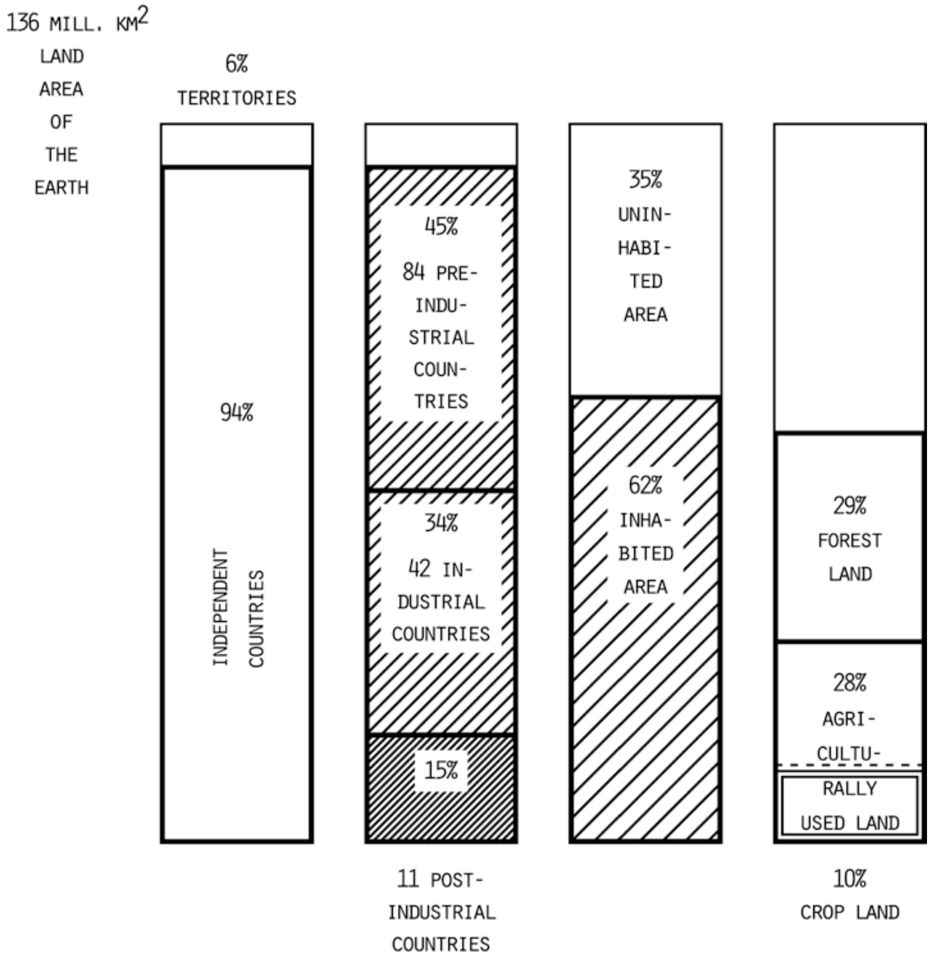


Figure I-7. World areas.

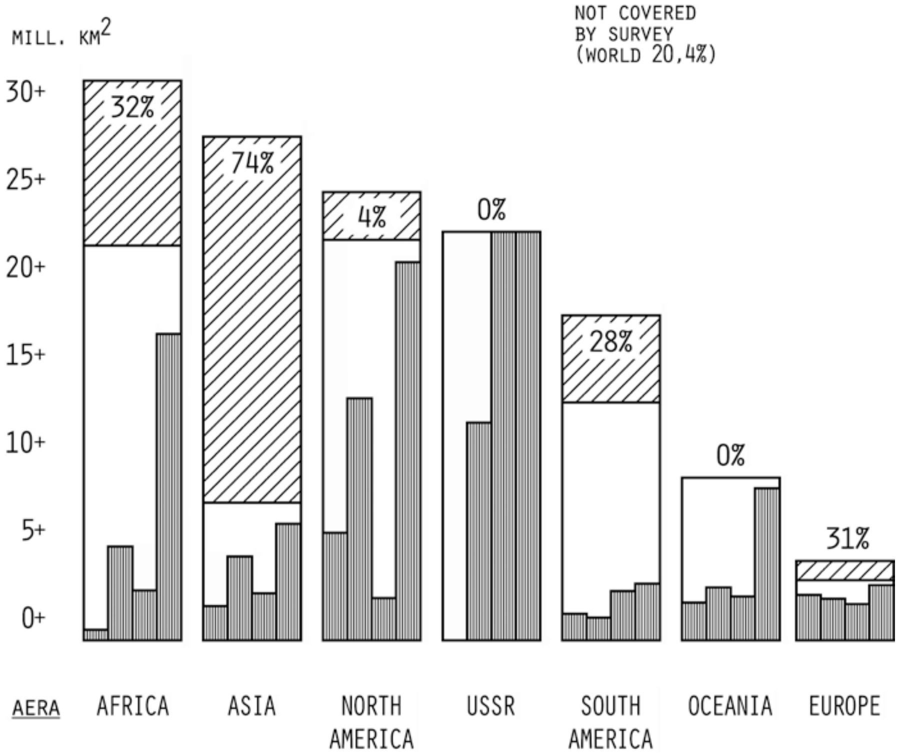
areas of the world makes clear what a small percentage post-industrial countries constitute. But we can say there is a definite need at least in all the inhabited areas as well as forest and cultivated land of pre-industrial, industrial and post-industrial countries. Of course, even in less developed countries, the special problems of urban areas must be considered.

There are a few parameters (Fig. I-8) which are important in deducing the need for a multi-purpose cadastral system. First is the density of population. Wherever the density is larger than one hundred inhabitants per square kilometer, then such a need can be demonstrated. In Europe, except for France which may soon reach this level, we have surpassed this level. This explains why most of the countries here do have cadastral systems. Another important parameter is the degree of urbanization – a very important consideration not only in Western Europe, but also in the United States, South America and elsewhere. The column representing the

COUNTRY	INHAB PER KM^2	GNP IN S PER INHAB	GNP PER KM^2	URBAN POP IN M	COUNTRY	INHAB PER KM^2	GNP IN S PER INHAB	GNP PER KM^2	URBAN POP IN M
NORTH AMERICA					ASIA				
CANADA	2,2	4440	9,8	17	• BANGLADESH	524	70	36,7	7,5
• MEXICO	29	750	2,2	35	• CHINA, P.R.	86	170	14,6	217,8
U.S.A.	22,6	5590	126	159	• INDIA	178	110	19,6	92,3
					• INDONESIA	67	90	6,0	25,5
CENTRAL AMERICA					JAPAN	298	2320	692	88,7
• EL SALVADOR	186	340	63	1,6	• PAKISTAN	85	130	11,0	17,0
GUATEMALA	52	420	22	1,9	• SRI LANKA	209	110	22,9	2,7
• HAITI	163	130	21	0,9					
					ARAB COUNTRIES				
SOUTH AMERICA					• ALGERIA	7	430	2,0	7,3
ARGENTINA	9	1290	11,6	18,1	• EGYPT	36	240	8,7	16,4
• BRAZIL	12,2	530	6,5	58,1	• IRAN	19	490	9,4	13,4
• CHILE	13,7	800	11,0	7,9	LIBYA	1,3	1830	2,4	0,9
• COLOMBIA	21	400	8,4	12,7	SAUDI ARABIA	3,5	550	1,9	1,4
ECUADOR	24	360	8,8	2,8					
• PERU	12	520	6,2	9,2	WESTERN EUROPE				
VENEZUELA	13	1240	15,7	8,3	FRANCE	94	3620	342	36,7
					F.R. GERMANY	249	3390	845	55,2
AFRICA					GR. BRITAIN	229	2600	596	41,9
KENYA	22	170	3,8	1,3	ITALY	184	1960	360	30,5
• NIGERIA	86	130	11,2	20,0	NETHERLANDS	402	2840	1141	11,1
					SPAIN	70	1210	84	21,8
					EASTERN EUROPE				
					G.D. REP.	156	2100	328	12,7
					POLAND	108	1500	162	18,2
					U.S.S.R.	11	1530	17,4	152,6

Figure I-8. Parameters expressing the need for mapping for selected countries.

G.N.P. per capita shows the principal capability of paying or not paying for an integrated survey system. The problem areas, without exception, pertain to developing countries. Figure I-9 indicates clearly where the real need for multi-purpose cadastral systems lies. While this problem may not be pressing in Europe, where we have already made considerable headway, it can be shown that these systems are urgently required in Africa, Asia and America. We now have a responsibility for advising these countries.



Scale range	Africa	Asia	North America	USSR	South America	Oceania	Europe
SCALE RANGE 1: 1 250 – 1: 31 680 (WORLD 11,6%)	0,3%	11,9%	23,2%	–	8,9%	18,3%	75,4%
SCALE RANGE 1: 40 000 – 1: 75 000 (WORLD 35,9%)	23,6%	55,2%	50,9%	40%	6,0%	31,8%	70,4%
SCALE RANGE 1:100 000 – 1:126 720 (WORLD 34,5%)	9,9%	13,1%	7,9%	100%	17,9%	19,7%	63,3%
SCALE RANGE 1:140 000 – 1:253 440 (WORLD 80,2%)	74,8%	87,8%	90,4%	100%	18,2%	99,7%	87,5%

Figure I-9. Status of world mapping.
(Acc. to "World Cartography" 1976, U.N.)

Adler

Dr. McLaughlin, would you like to make another comment on this?

McLaughlin

Once more I find myself following in the wake of someone with whom I am in complete agreement. When we talk about a multipurpose cadastral system in North America, we are talking about a system founded upon the integrated survey framework to which other types of land registration, community planning and environmental information is noted. As an aside, I might note that in North America our problems are compounded by the concomitant transfer from passive to active registration of land titles. Mention has been made of assessment requirements and I should point out that the very future of this form of taxation is in some doubt.

I should also like to follow up on Dr. Konecny's data bank discussion. At one time we also were envisaging monopolistic, centralized computer data banks – perhaps a natural evolution of the integrated survey concept grounded in the belief of scales of economy. Similarly, other people have argued for large centralized data banks, but based upon a geographical information approach as opposed to the cadastral philosophy. This concept promoted by the geographers focused on small scale, low resolution information technologies capable of economically providing macroscale data. While of some regional planning value, this approach disregarded the high resolution problems at the plan implementation and regulation stage. Hence we find a swing back to the multi-purpose cadastre concept, but in a decentralized model.

Let me conclude with a couple of caveats. First, the systems we are talking about are not directly people-related. There is a strong social bias at this time to not mating physical and people based data systems (such as by mating parcel and social insurance identifiers). Secondly, we are talking about systems that contain only information available to the general public – these systems will not contain confidential information.

Van Twembeke

I would like to clarify the difference between the three types of cadastre directly influencing the multipurpose map. The distinguishing characteristic of the positive, the negative and the multi-purpose land registration systems are:
<u>The positive or real system</u> (judicial cadastre). The system is based upon legally recognized and maintained parcels and the record is a public one. All the factors influencing the destination of the estate are noted in official registers, and each deed of assignment is controlled by officials, responsible for recording and indexing title documents. The boundaries of the parcel are based upon a survey, and a boundary mutation requires a new survey. The TORRENS approach incorporates a tract index system including tax and census data as well as deeds and mortgages. The judicial and the TORRENS cadastres may be distinguished by the nature of the title registered and the registration and warranting of boundaries.
<u>The negative or personal system</u> (fiscal cadastre). In this system the identification of the landowner plays the leading part with regard to the real estate. The system is characteristic of countries with a Napoleon Code. The official record notes only the public character of the title documents, and the maps are more or less accurate without legal force. Location of property on the ground is difficult to ascertain, and there is no assurance of the fixed position of boundaries. A fiscal cadastre often incorporates a tract idea system.
<u>The multi-purpose system</u> (ecological cadastre). The purpose is to provide a variety of land tenure registration and information services as required by the needs of the community including information for the efficient assessment and legally recognized interest in a parcel of land. Other components of a multi-purpose system are found in an engineering project including planning, design construction, maintenance and also in the social function of such agrarian activities as a developer of the open space preserving natural resources and fulfilling the function of entertainment.

In many countries, ownership is the most important factor influencing the accuracy of maps. The multi-purpose map has a technical and fiscal objective, and the accuracy must be justified economically.

Adler

Thank you, Professor Van Twembeke. Are there any remarks from the floor, gentlemen?

Clapp

Professor McLaughlin, you have mentioned that the U.S. government will be funding the cadastral as opposed to geographical approach in forthcoming research endeavours. While I appreciate your emphasis, in fact these funds will be directed at reducing title transfer costs. We can only promote the multi-purpose cadastre thrust indirectly.

McLaughlin

There is a problem here in trying to generalize. I realize the emphasis of the H.U.D. research will be directed at the transfer cost issue, but would suggest that this will create the type of environment where cadastral concepts can be cultivated.

Adler

I would like to take up Professor Konecny's point stressing the importance of monumentation. I really feel that monumentation is overestimated. Actually we need monumentation at the moment of the survey whether it is a ground, topographical, or photogrammetric survey. That is one thing. Basically monumentation is for the purpose of the recovery of the boundary at any desired time. I feel that stress should be placed on the proper monumentation of the control network rather than on the proper monumentation of boundaries as it is in many countries. I think that in the developing countries, with none of this tradition of marking boundaries, there is room for switching the trend. Don't forget that monumentation and all ground survey control are perhaps the most important and perhaps the most expensive part of the operation. Would you like to say something about this, Dr. Konecny?

Konecny

Well, Dr. Adler, I don't know whether I should. I will make a few comments, although I think that probably a man of practise should answer this question. I believe that my feelings will be that in Germany right now this is being done and to suggest forgetting about monumentation would require the complete restructuring of the orientation of the survey profession. Then again, once you survey a point, it is now not that expensive to put additional monumentation in. The public image of the surveyor in that particular instance is a little higher if he can show something. If he can show only the coordinates they are not very well believed. On the other hand, if you do have something on the ground, the monumentation, it is visible. Again we must think also about others, that we have other procedures today, we have photogrammetry. If we do not have monumentation how would you like to tie photogrammetric procedures to the ground?

Adler

Yes, well, I said monumentation at the moment of the survey, in other words, if you want to presignalize boundaries for photogrammetry, this is certainly an example. You can take the signals away and you will still be able to recover the boundaries. In the cadastral structure, what is very important is the feeling of the people that they can have the boundary recovered at any time and that the boundary is guaranteed by a legal system. This is not so much perhaps appreciated in Europe because in Europe there is a tradition of boundaries and a tradition of land ownership, but in the developing countries, where the property has changed hands quickly in the last twenty, thirty, forty years, this is a very important factor.

Au

The monumentation of boundaries is truly a German tradition but there are certain states in Germany which do not force the owner to monument the boundaries of his parcel. In the northern part of Germany, there is only the need to monument the necessary control points in order to find the boundary points. But normally in Germany the monumenting of boundaries is forced by law. But apart of this I know, for example, in Thailand, even there, there is a need for monumentation; the people are forced to monument the boundaries as a legal reference.

Ackermann

I am somewhat confused as in my opinion monumentation as such has nothing to do with surveys. Monumentation has often been in existence long before and independent of surveying. Monumentation means establishing a physical and lasting representation of a boundary. Surveying of monuments is a subsequent step. It provides description and mapping of the boundary. It also provides the means for checking or re-establishing monuments to which a legal function may be attached.

Adler

Yes, of course, Professor Ackermann is right, but I have a feeling that some of these things are exaggerated in importance. As the story goes, during the time of the British mandate in Palestine, there was a head man of the village who was responsible for all the boundary markers within the village and the survey party would come to demarkate the boundaries and then turn them over to the head man and tell him that he was personally responsible for all the markers. The story goes that two years after the survey, the district surveyor appeared and he couldn't find a single marker in the field so he came to the head man and said: "Where are all the markers that you are responsible for? –– They are all there under the bed in the other room, you will find them all there."

Perhaps, really the physical marking of the boundaries is exaggerated in importance, particularly in the view of the fact that we can have repeated aerial photography taken of the area where these boundaries are permanently recorded and can always be recovered through the network of control points. Well, gentlemen, let's turn to the last question of this session, and this is a brief <u>discussion of graphic vs. numerical information system</u>. If we didn't have a coffee break, we could probably argue about this topic until tomorrow morning. Would you like to start, Dr. Konecny?

Konecny

When we think of the question graphical vs. numerical information what comes to mind first is the historical distinction between the two. The graphical cadastre, based upon plane tabling, may still be found in certain areas of Switzerland. The main importance was simply to have a map. This particular map would then be revised by further surveys and it was the only legal official record. On the other hand, we had a numerical cadastre in a form of a numerical survey record which with the modern computer technology could permit us to compute coordinates and describe each point by the coordinates. Previously, this was not possible; we had to find the survey record.

It is quite clear that with modern technology we should not talk about this historical graphical information system but we should try to keep it numerical. The numerical system is preferable because it lends itself to the computerized information system. We know that a numerical record is susceptible to automatic drafting, i.e. to plot points, draw lines or connect specified points by sophisticated computer programs. This is economically possible today in highly industrialized nations, but the developing countries are already thinking along the same direction. One of the main advantages of numerical records is their capability to lead to an integration of various survey methods. A numerical record need to distinguish between different data sources, i.e. ground survey, digitized map or numerical photogrammetry. However, we must admit that when we go to a numerical system, then updating of such on automatic record becomes much more complicated.

First of all we should realize that the human being is mainly an optical processor. Anything he sees in graphical form he is able to visually comprehend, inferring from that immediate results. Ambiguities only occurring in numerical form are usually hidden or do not appear at all; this is one of the drawbacks of purely numerical procedures. Currently suggested interactive display systems entail more complicated equipment, thus simply inducing the question of costs vs. usefulness. Small organizations will probably stay with the older systems, larger ones will of course go to automation.

There is a further point to be made, which ties in to what Dr. McLaughlin mentioned earlier; viz. that numerical information systems are integrable into the domain of computer planning. Considerable funding is presently being spent in the computer planning business, particularly in Germany. As surveyors we should be aware of the fact that raising funds for such a new methodology is much easier than increasing funding in the cadastral area. Fig. I-8 should show that planning by boundaries as proposed by Dr. McLaughlin is not possible unless we have put the cadastre on a numerical basis. Planners do that usually with a so-called environmental data bank (Fig. I-10). We obtain the analog records, i.e. the map, regardless of whether they were measured by analytical or analog photogrammetry, or by ground surveying. The maps are topographic by nature, carrying additional information from ground collection methods, e.g. photo interpretation, drilling. Topographic and thematic maps are also used in combinations.

All these maps must be available in digital form. There are two ways to obtain this state, viz. digitization by line following or by gridding. In the line fol-

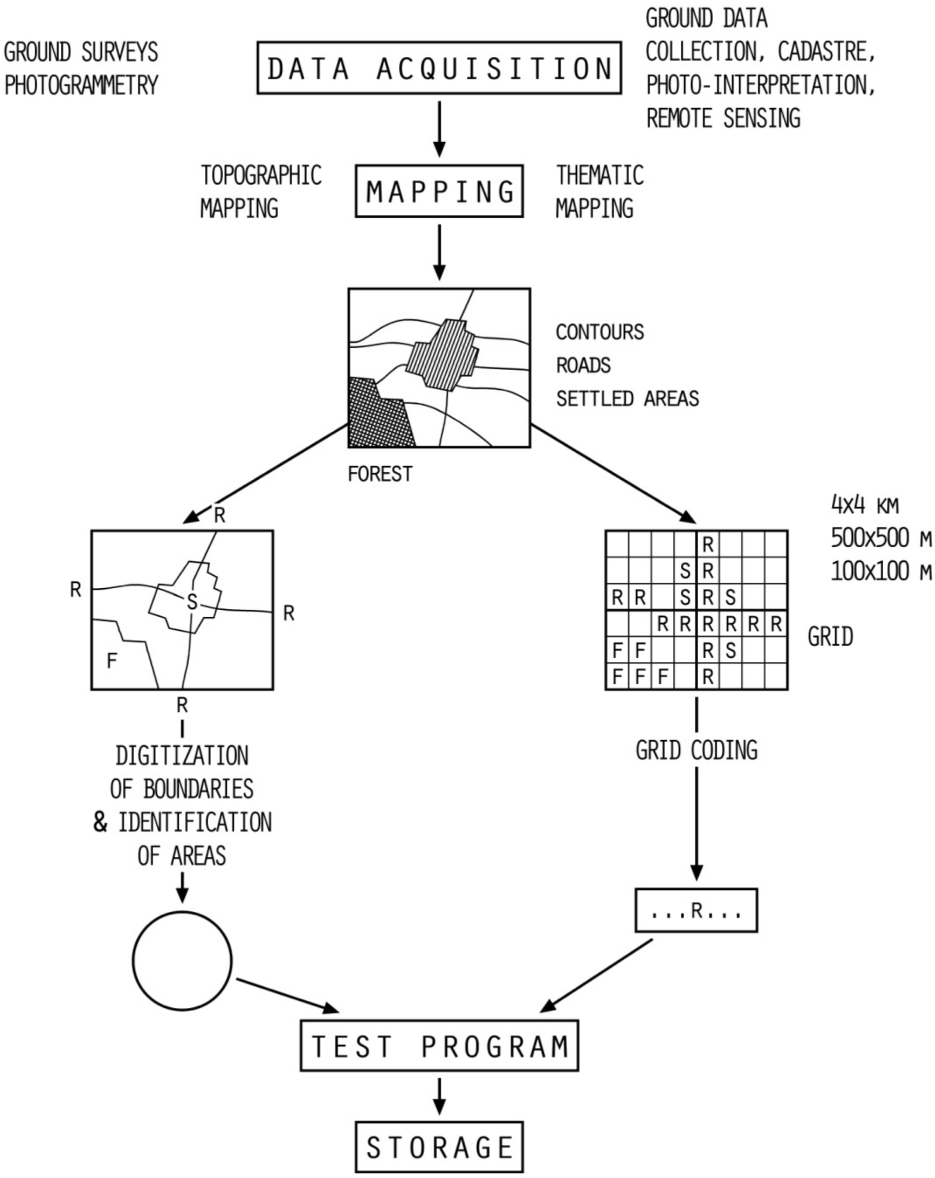


Figure I-10. Data acquisition for environmental data banks.

lowing method roads, boundaries of settlement, forests, parcels or other properties are manually digitized. The data are put on magnetic tape for subsequent computer processing. It seems that the planners have not yet solved the problem of separating the digitized boundaries, i.e. segmenting the original data structure in a more manageable form by computer. Although the surveyor has not solved it either in automatic mapping, he should be more amenable to finding suitable solutions.

The gridding method mentioned by Dr. McLaughlin has more or less failed. In North America the planners have unexpectedly gotten into considerable trouble by defining grids with spacings down to 4 km, 500 m or even 100 m. All the desired map properties were labelled by suitable simple or overlay codes. From there on the computer was asked to do the planning (Fig. I-11).

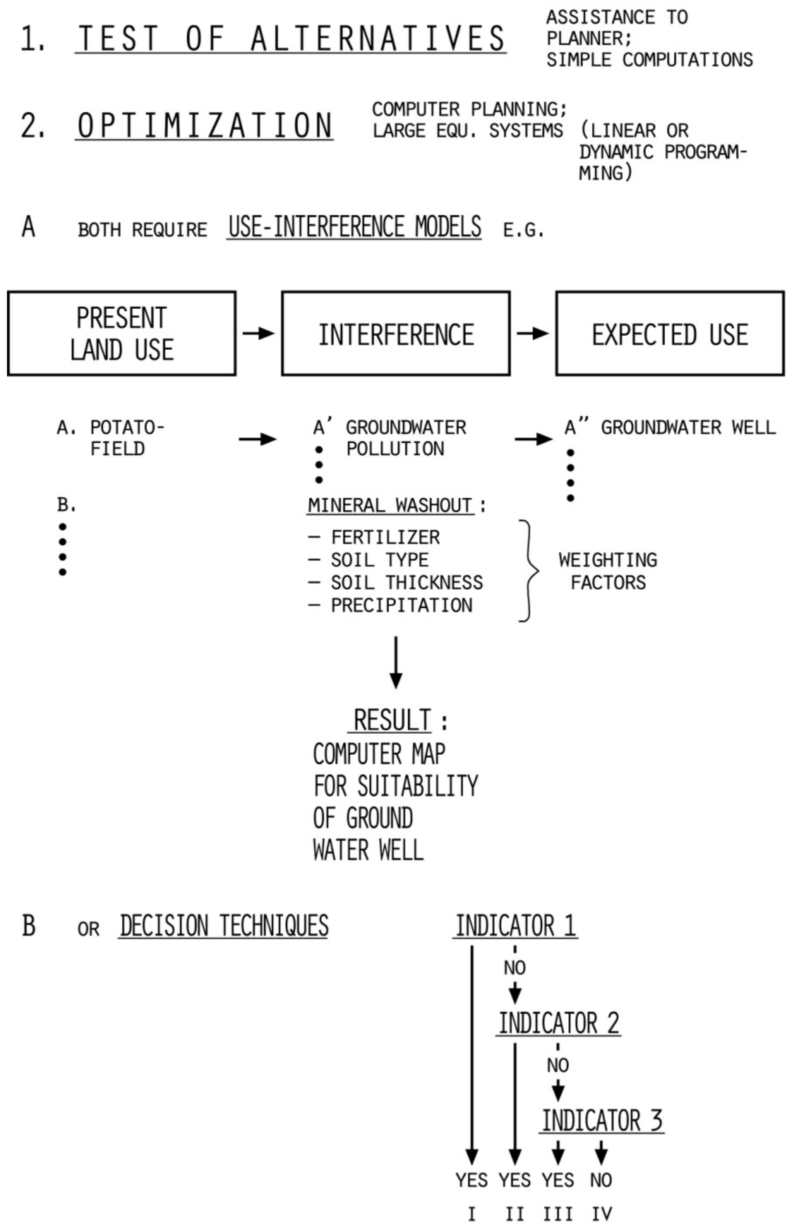


Figure I-11. Planning by computer; schematic.

Computer planning has worked in two ways. The simpler one merely assists the planner in the testing of alternatives. Real computer planning, however, is a case of linear or dynamic optimization. In comparing present land uses with expected uses, all kinds of inferences are found. Optimal solutions presuppose reasonable weighting schemes for these influences, and require large computer programs. The surveyor's contribution is providing the necessary basic data as well as his knowledge in the area of numerical analysis. If we succeed in convincing the planners to share in the present investment we could then jointly work towards a common goal.

Adler

Stay with us for a moment. Are you of the opinion then that all cadastral boundaries should be defined digitally?

Konecny

Numerically, I would say.

Adler

How would you deal with a wavy line of a boundary?

Konecny

There is no problem because a wavy line consists of many points. Of course, in most German states by defination the boundary must be a straight line between two points.

Adler

Thank you very much, Professor Konecny. I don't know, I'm not sure whether I agree with this approach completely because the size of such a data bank would be tremendous and I think that some of these systems, because they are just too good to be true, are never realized. There is not getting away from the graphical product but I think that we should have a base that is either a map or an orthophoto overlaid with different types of numerical information which can be plotted separately or together. An example of this would be perhaps, what I have here (Fig. I-12). You see part of an orthophoto, and the cadastral boundaries and the control points are presented as an overlay. This overlay was taken from a data bank and automatically plotted together with the framework of all the coordinates and all the control points in the area. This was generated directly from the computer, but to hold the contents of the basic map in the computer would make the system, I fear, unwieldy. Professor Van Twembeke would you like to comment on this point further?

Van Twembeke

The information system is to be reached in two steps:
<u>The large scale map as the first step of the land information system</u>.

Up to now large scale mapping has been inspired exclusively by the application of land tax and the delimitation of property. On this type of map we find mostly administrative inscriptions, but the documents are not utilizable in the case of specific problems surpassing the above-mentioned objective. At present the cartographer is compelled to investigate the whole problem or large scale mapping in the prospect of a multiple purpose cartography. Producing such a map is a very important part of an integrated entity, and the effectiveness of its use depends on the efficiency of the environmental or physical terrain information as well as an proper-

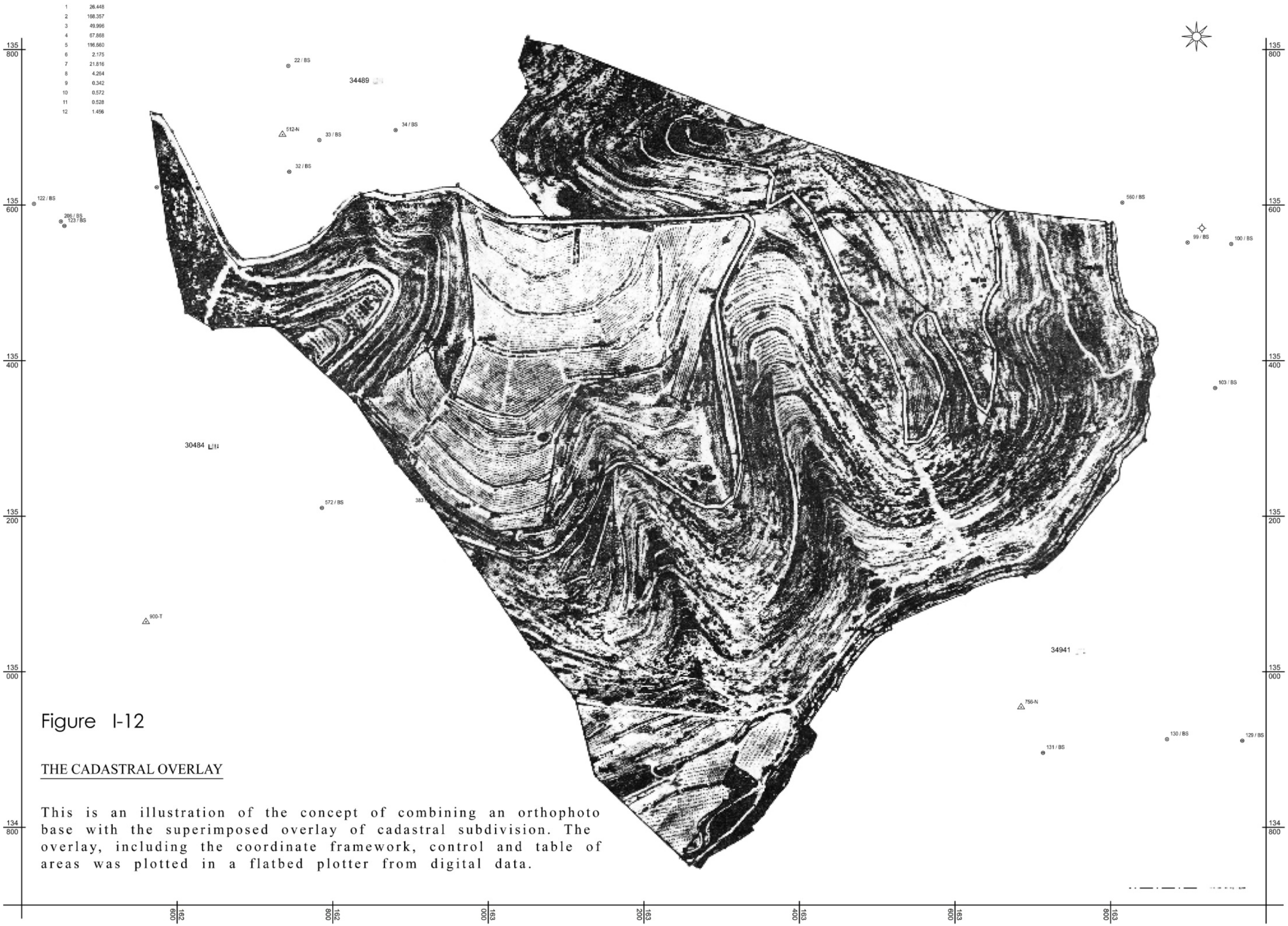


Figure I-12

THE CADASTRAL OVERLAY

This is an illustration of the concept of combining an orthophoto base with the superimposed overlay of cadastral subdivision. The overlay, including the coordinate framework, control and table of areas was plotted in a flatbed plotter from digital data.

ty and ownership information.

It appears that modern surveying technology can provide the necessary survey base if the problem is approached in an integrated way. The maps should be designed to serve, simultaneously, a number of public and private functions. But what are the user requirements in order to provide the best possible map system? We have the choice between a line map and a photographic map or a combination of the two.

In all these cases the advantages of large scale photogrammetry has been proven in the past ten years, and compared with modern field survey this method is very advantageous both in time and cost.

The requested cartographic document has to appeal to an integration of the three photogrammetric restitution methods applied today, namely the graphical, the analytical and the photographical. Each map covers (1 km x 2 km) and the dimensions are (0,50 m x 1 m).

The mixed numerical-photographic map can be seen as an arrangement of the photographic and the numerical restitution. In this case, we dispose of a <u>framework of control points</u> marked in the field, visible on the photographs and known in ground coordinates. The experience makes clear that the complementary work increases considerably the metric value of the documents. The topographic points supply the bases on which a detail survey by classical topography can be made later on. <u>These points make up the spine of the metric document</u>.

The advantages of a photographic map obtained by rectification or by orthophotography is no more discussed today. In fact, the photographic map makes clear the impossibility to integrate all desirable information on a conventional map while the abundance of information is even dangerous for an unwarred user of them. The inconvenience of abundance does not exist in the case we are concerned with, because we only consider the scales 1:1000 and 1:2000.

The photomap is completed by "<u>permanent elements</u>" such as the grid, contour lines, limits of pedological zones with the indication of their official symbols, toponymy, and so on. Each "<u>variable element</u>" is reported on a transparend grid overlay which can carefully be aligned over the photomap: limits of parcels of property, limits of parcels of exploitation, overlay with the topographical supply points (altimetric and planimetric), underground topography, and so on. Each important terrain factor is assigned a transparent overlay. The overlay containing variable elements is updated every year while the orthophotomap is remade every five years.

In urban areas the problem is somewhat more difficult on account of dead angles, and a larger amount of field completion survey will be needed.

However, in view of the fact that existing maps are not up to date, the proposed technique is excellent for all kinds of studies and planning, and should be considered as being able to provide a rapid and economical solution.

<u>The analytical management system as the second step of the land information system</u>.

Each of the management processes involves several decision makers and requires that coordinated decisions on several levels be made. Lack of coordination between different data gathering groups leads to expensive and unproductive results.

Decision makers have to model complex relationships between activities and have to determine rapidly the impact of alternative policy decisions on these relationships. The development of an integrated communication database will supply the information needs of our society. A numerical base can be considered as the liaison factor between all the different components of the land information system in relation to cartographic, administrative, juridical, statistical or other specific factors. The primary outputs of such a system should be computer prepared thematic maps on a graphical computer display or final drawn maps.

The potential of utilizing computer-assisted methods has been recognized in cartography. In this way, a virtual map can be converted into a real thematic or general map as required for analysis.

Interactive methods offer the possibility for the cartographer to work on the map while it is in a virtual state.

Another major function of the system is the linking of the different information files stored in the computer. For a given input relevant attribute data can be generated. The system should also allow a link to specific computer files via a cross reference system.

The proposed multi-purpose integrated land information system will have the very interesting advantages of joining together several partial documents and data banks giving each of them a particular aspect on an ecological cadastre.

Adler

Thank you. Dr. McLaughlin, would you like a comment on the numerical vs. graphical approach?

McLaughlin

Our current thinking is that by and large we will have graphical bases, largely graphical systems, which will evolve digitally on an overlay basis. The tests will be information quality and information economics. These will dictate the rate of change to a digital system. While the tremendous, even liberating advantages of the digital base are appreciated for a wide variety of users, the associated front-end costs are by and large too great at this time. As well, there are significant software problems to be resolved.

Barwinski

I would like to comment to what Professor Konecny said. Our working goal in Germany is to have a digital cadastral map. We determine coordinates for all boundary points. And not only for the boundary points we want to have coordinates, but for the edges of the houses, too. So we hope to get a basis for a digital cadastral mapping in the future. We are developing a corresponding program now, this year, and in the next two years. Then we hope to have a map for planning and other purposes.

Dubuisson

To answer the question concerning numerical vs. graphical systems, I want to speak about the integrated survey system in France, in particular for urbanistic purposes.

It is named Géomatique. It is a geographical science based on computer systems for fundamental and data reference source in numerical files, combined with coded description of correlated topographical elements. This information is used for data banks and for a fast, a simple und multiscale graphical readout of selected elements via computer assisted plotting. Frequent and easy interactive updating is possible.

The most frequent use of this system is usually for topographical and thematic graphical expression. This way is used in urban planning of various towns, since six or seven years.

Andris

We have a system which I will tell you tomorrow about. It is a system in which we can integrate graphical and numerical data (in the sense that integrated survey means graphical, numerical, and other nongraphic data as basic information). Therefore, "graphic vs. numerical" is out of question for me.

Konecny

Just one very brief comment. In Germany we are able to have a numerical cadastre because our survey record is numerical to start with. We just haven't computed it; but today we can readily compute coordinates, so therefore it is possible. Of course, I would like to say that it would be bad to advise anyone without an appropriate data collection process to start a numerical system. Also, presently I think that it would be difficult in implementing such a system; but the question remains that if one works towards it, one expects benefits.

The last point that does not really refer to only our job but also to the planners' job. They believe that if they have the records, then the human mind which is a very slow and imperfect correlator should be substituted more by the computer. This fact may easily be appreciated when looking at a planning map with its various overlays. The total amount of information, with the many relations correlating these overlays has become so complicated that humans are not in a position anymore to properly understand what is happening here. An individual overlay structure in itself does not mean anything. One can at the most perhaps correlate three or four such overlays together. The computer is not limited to this figure and can add and relate many more. That was all I wanted to say.

Adler

Well, I would like to thank all the participants in the discussion for their active participation. And, in particular, the panel, Dr. Konecny, Dr. McLaughlin, and Professor Van Twembeke. This session is now closed. Thank you, gentlemen.

S E S S I O N II

PHOTOGRAMMETRIC STANDARDS FOR INTEGRATED SURVEY SYSTEMS

Moderator	G. Konecny (Germany)
Panelists	F. Ackermann (Germany)
	B. Dubuisson (France)
	A. Grün (Germany)
Discussants	J. Polman (Netherlands)
	K. Heiland (Germany)
	K. Barwinski (Germany)
	U. Van Twembeke (Belgium)
	P. Waldhäusl (Austria)
	H. Andris (Switzerland)

This session dealt with the following issues:

(1) What are the capabilities of photogrammetry in collecting and updating positional data for integrated surveying and mapping systems?

(2) What are the theoretical and practical accuracy limits of aerial photogrammetry in mapping and densification of control networks?

(3) Production of numerical maps: off-line or on-line?

S E S S I O N   II

Konecny

I would like to introduce the subject for Session II. We have been asked to cover the topic of photogrammetric applications in a cadastral sense. Three questions have been posed: first, what are the capabilities of photogrammetry in collecting and updating positional data for integrated surveying and mapping systems; second, what are the theoretical and practical accuracy limits of aerial photogrammetry in mapping and densification of control networks; third, should the production of numerical maps be off-line or on-line? Now, again some of the panel members will have to say when we stray across these questions and in order to lengthen the time of our discussion I will propose that we make the remarks to all of these questions at the end of the session in the way that they are written in the program. But let me first make a few general remarks.

I think we can start out with premise that photogrammetry is not the only data acquisition method for a multipurpose cadastre system and that it must, of course, be considered a competitive possibility with ground surveys. The deciding questions of whether to use photogrammetry or not will be firstly: "Can photogrammetry reach the required accuracy;" secondly, "Is photogrammetry capable of doing things faster?" and thirdly, "Is photogrammetry capable of doing things cheaper?" I understand that such questions of faster and cheaper are not really the concern with this session.

What is more complicated as is illustrated in the first slide (Fig. II-1) is really that we are talking about the usage of photogrammetry. We must consider that it is not only one process but that it is really a whole system of processes. While confusing, nevertheless, we must see that in one sense we are producing by photogrammetric means a coordinate list, by aerial triangulation of points, for example. Another graphical output procedure has been the map. Then of course we have as a third topic a photomap or the orthophoto. We will see that to reach the coordinate list, the map and the orthophoto we have not only one direct way but we can go cross-wise. So when we are talking about the usage of photogrammetry as opposed to ground surveys we cannot consider only one method vs. the other but we have to consider them both with respect to economy, with respect to accuracy, and with respect of speed. With that let me start the discussion by calling on Professor Ackermann. He will speak essentially on the first and second topic.

Ackermann

The question has been raised as to whether or to what extent photogrammetry is capable of collecting positional data for integrated surveys. My answer is simply that I consider photogrammetry the tool "par excellence", which is very well suited for such tasks, that means for combining various kinds of information and relating them to a common reference system. This is particularly true for relating metric and geometric information with other image information. This statement is

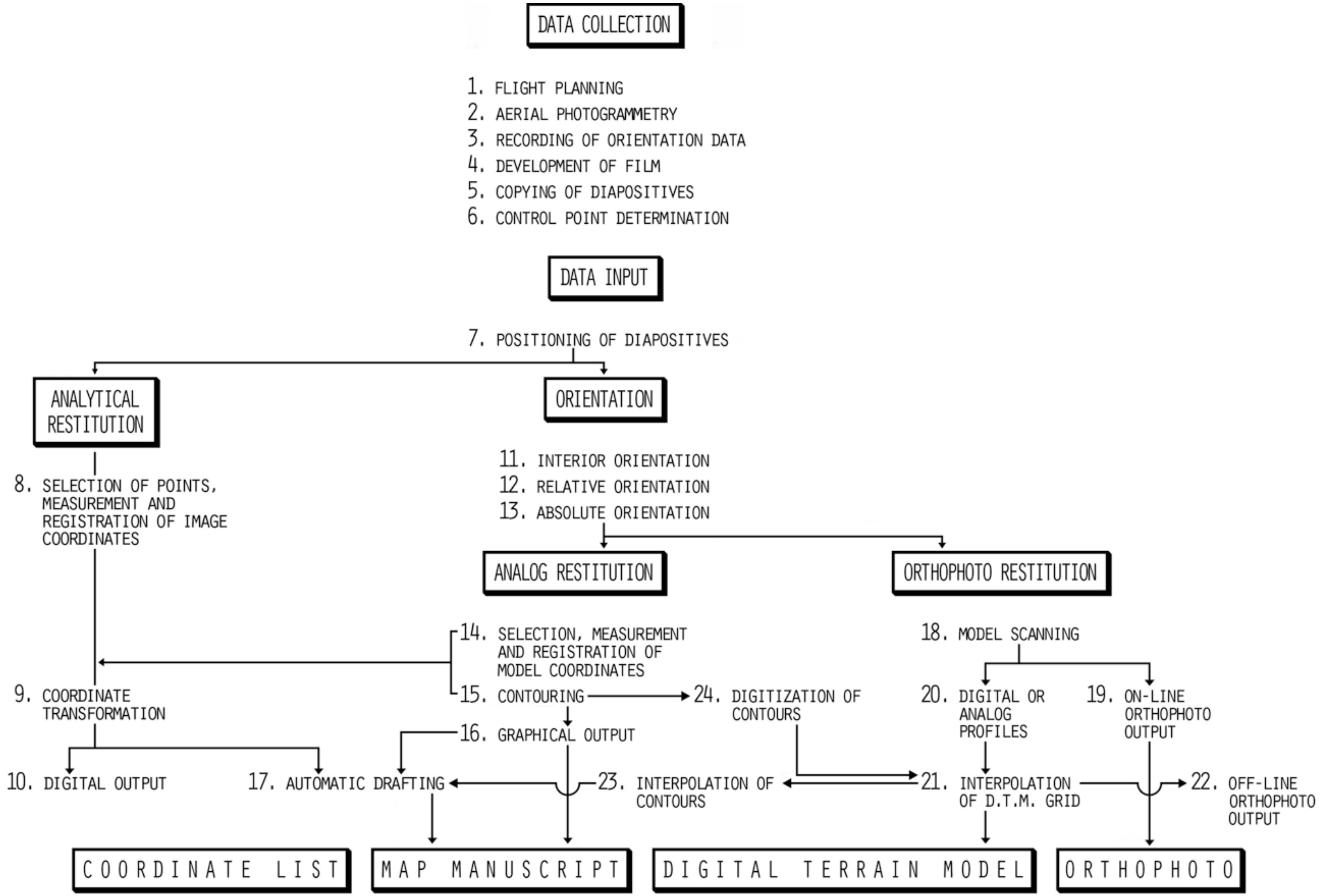


Figure II-1. Data Processing in Photogrammetry.

based on the fact that a photograph is unique in many ways. It is a signal storage system on a geometrical basis with tremendous capability. When working with photographs we make combined use of their various properties. First of all, we can identify features, objects, and details. Secondly, we can establish structural relations amongst the identified objects. Thirdly we can at the same time use the photograph for geometric measurements for the purpose of absolute and relative positioning of features. And finally we display the results of the information extraction graphically or numerically with regard to any desired reference system. It is really this combination of different aspects of information which is the unique feature of photographs. There is no other technique which has similar properties. Therefore, I believe that photogrammetry is an outstanding tool for combining information acquisition with positioning information. There are limitations of course. For instance, if too much accuracy is demanded or, if information has to be integrated which cannot be deduced from photographs, such as legal or administrative information. So, nobody claims a photograph to be the only source of information. But it is a major source of information. This statement carries enough weight, in my opinion, to turn the initial question around and to ask why everybody does not use photography for collecting and integrating environment information.

The answer is, perhaps that we look too often for specific features only. For instance the traditional cadastral systems have put much emphasis on extreme accuracy of selected features only, such as boundary points. For such specific features it may very well be under certain circumstances that, for instance, ground survey techniques are most suited. The point is, however, that in such cases additional information is not acquired at all which would be accessible in the photograph. Thus, when thinking for instance about establishing integrated cadastral systems in developing countries it is really the photogrammetric approach only which is feasible, because it is capable of acquiring various kinds of information, of relating them to common reference systems and of mapping and displaying them accurately on a geometrical basis.

Grün

I want to underline what Professor Ackermann just told us. I think that photogrammetry is an integrated survey system in itself, if we look at all its possibilities and at all its possible results. Photogrammetry is used not only for the determination of point coordinates but also for planning purposes with regard to land consolidation, for planimetric and topographic mapping, and for orthophoto production. Besides this, a new idea is being discussed, viz. photogrammetry may also be used for the establishment of a computerized photogrammetric data base. This means the following: the adjusted photogrammetric data, such as point coordinates, orientation elements, and calibration data would be stored in a computer storage medium. At any time one could determine precise coordinates of any photo-identifiable object; this might be done by means of inexpensive monocomparators and minicomputers. Other possibilities arise with the use of analytical stereoplotters.

Dubuisson

On the first question regarding the capabilities of photogrammetry in collecting and updating positional data for integrated surveying and mapping system, I have a few remarks:

a) If integrated systems are accepted as numerical (which is obvious), capabilities of numerical photogrammetry are considerable, even incommensurable, in an analytic mode.
b) A proper organization of flights for updating on the basis of new positioning systems permits the solution of all revision positioning problems.
c) The fundamental problem of integrated data, however, is the coordination and coherence of purely geometric numerical data for photogrammetry (e.g. analytical) as well as remote sensing, in which updating – of a cultural or economic features – shall be much more frequent than the revision of traditional plots. With respect to this question, I should like to point out that it is now possible to obtain simple aerial positioning of the aircraft with an accuracy of about one meter with the TRIDENT system. More, by means of a proper methodology in an analytical plotter based on a set of several contiguous models, this permits the in-flight determination of points with RMS errors not exceeding 0.35 m – and all this without ground surveys.
d) In any event, the requirements must be classified, and only then will it be possible to answer questions regarding the use of photogrammetry for each problem, after having studied the cost-benefit ratio for each of them, and where data computer processing speed plays a role.
e) On the subject of speed, it should be noted that aerial data positioning acquisition is the only means which permits "immediate" rough processing, followed by more complete handling at a later stage, and, finally with maximum "ultimate" precision and security.
f) The geometrical coherence of data of a pair of exposures, rapidly changed into coherence of an aerotriangulation unit, is the numerical form best adapted to universal processing and to computer-controlled stereo-compilation of remote sensing and cadastral mapping.

Konecny

Thank you very much. I would like to sort of summarize the general outcome of the discussions. Obviously there are three or maybe four photogrammetrists here who are famous. Yet I think that we have all agreed that photogrammetry is not the only method. However, I think that everyone has spoken loudly that photogrammetry is the method par excellence as it has been stated, or, if you want to say, paragraph number one of the photogrammetry text is that what you cannot do by photogrammetry, you must do on foot. I believe that there may be some disagreement to that kind of philosophy or to some of the general comments that have been made. Would anyone care to comment?

Polman

Photogrammetry is of course a very important tool of surveying but we in Holland don't use photogrammetry for small projects. We use it only for cadastral surveys in large resurvey projects. Photogrammetry is a good method but not for smaller projects and for revision surveys from the point of view of the cadastral efficiency. In that case photogrammetry is too expensive because you cannot go out and take one photograph, for instance. In fact, the greatest part of our survey activities is divided over a large number of small projects, where photogrammetry is not suitable.

Ackermann

Of course, that is very true. My initial declaration referred to the general situation. However, there are many conditions in actual cases which require considerations. One of them is that in small surveys photogrammetry is usually not competitive for economical and practical reasons. Also photogrammetry often has problems in urban surveys with accuracy specifications or with hidden objects. Moreover, the modern ground survey methods have made considerable progress, too. It is really a question of sound engineering as to which method to apply under given circumstances. However, I maintain and I really want to make this point clear, that in my opinion, conventional survey systems only gather part of the information which certainly should be collected. This is particularly true with conventional cadastral surveys. In a modern multipurpose cadastre all relevant objects and features on or above or below the surface of the earth should eventually be recorded. It is with regard to simultaneously collecting and relating environmental information of different kinds that photogrammetry can offer unique capabilities. Naturally, the term photogrammetry is here not restricted to conventional photographs, it rather includes also remote sensing imagery, if applicable for the case at hand.

Konecny

If I may shortly comment in regard to this. The question has come up: "Can existing procedures be competitive enough where you have small areas?" I think in those cases where the surveys are for rural reallotment purposes, this is a different story. I am sure that Mr. Heiland will be able to give us some information from his experience in Baden-Württemberg.

Heiland

Yes, I will surely, indeed. In South-West Germany in our rural reallotment agency we need terrestrial surveys and photogrammetric means for cadastral survey and large scale topographic mapping. And for us there is no question about accuracy or about economic output of the method. It is more in such a sense as Professor Ackermann has said, that if some more information is to get out of the pictures, such as coordinating boundary points and topographic large scale mapping, for example newly built highways or large areas of new topographic sights, then we go into photogrammetric means. If it is only to coordinate points then one should consider whether to use terrestrial means of photogrammetric means. Of course, if the project is a small one, modern terrestrial techniques to pick up coordinates are much better than to start a flight. As far as integrated surveys are concerned, we have just now in the first session seen, that there are integrated systems, which go from a flight to a map, or from a flight to a picture to coordinates and other information is put-in such as legal information; but you can, of course, integrate photogrammetric pick-up with terrestrial pick-up as we do it. We combine terrestrial surveys with photogrammetric surveys in an integrated system but we have not a name for this system, but we do it. There are some other countries that do the same, as in Austria, in Bavaria.

Konecny

Thank you very much. That was a comment from Southern Germany, and I believe we shall have another South German comment from Dr. Grün.

Grün

We are sure that there are a lot of parameters influencing the use of photogrammetry. If we want to consider only the number of points as a criterion for economy, then I remember an investigation by D. C. Brown, which shows us that there have to be adjusted at least 300 points if photogrammetry is to become economical as compared to ground surveying.

Konecny

If I may have perhaps a short "North German" comment. Right now in Northern Germany we have a program in which reallotment offices are considering certain projects that seem worthwhile to be done with photogrammetry and some that are not. It is simply for the following reasons: What costs very much is not the photogrammetric process but the signalization. Signalization covers about 40% of the costs and is generally carried out by surveyors, i.e. by a different type of group engaged in the terrestrial survey. In other words, if you replace one group that has been active in one particular field, it becomes very difficult to produce another group, perhaps a governmental group, that should do things in another way. But nevertheless, a compromise has been found lying more or less in that vicinity where a reallotment area is larger than 2500 ha. There it is done by photogrammetry despite signalization, and where the area is smaller it is done "on foot", specifically "on foot" with new technology. Automatic tacheometre has really made an impingement, for it has become very competitive indeed.

Barwinski

I want to say that we need not only an integrated survey system but an information system. There is a lot of information which cannot be given by photogrammetry. For example, the usage of a building, the number of floors. We need the number of basements. We need the number of apartments, we need data about the construction of the building. All these elements cannot be given by photogrammetry. In Germany we have only small regions where we can use, for example, cadastral photogrammetry.

Dubuisson

I want to impress on you that the question is not exactly to use or not to use a new graphical base of measurements. The question today, with existing cadastre with actual accuracy, is to use it in order to locate physical, social or/and economical information. It should be added that this is the real difficulty to separate the cadastral base from the question of the general informations.

Computer processing gives an orientation for useful graphical, thematic and cadastral correlation.

Konecny

Thank you very much. In conclusion, I believe, we can say that there is a necessity to improve our methods, and that we may expect a better cadastre if we use the interpretative capabilities of photogrammetry.

Perhaps we can now go to second question. The second question refers to the <u>theoretical and practical accuracy limits</u> which can be achieved in mapping and in densification of control networks. Perhaps Professor Ackermann would like to make a few remarks in terms of the accuracy of analytical and analogue methods.

Ackermann

When talking about the accuracy capability of aerial surveys we hardly refer, any more, to the accuracy of photogrammetric mapping. It has been sufficiently established that horizontal and vertical photogrammetric accuracy is quite adequate for mapping at practically all feasible scales, up to very large map-scales, too. With mapping, the accuracy limits are not usually approached, except perhaps for the height accuracy.

When we talk about the accuracy capability of photogrammetry we have in mind the obtainable limits which can be approached by numerical methods. Their application is high precision point determination, for the purpose of cadastral surveys of for network densification. The development has reached accuracies for image coordinates in the order of two or three microns. Tests and practical application have confirmed that such accuracies of image coordinates can be realistic under practical working conditions, too. The accuracy obtainable for adjusted terrain coordinates is a matter of propagation of errors. It depends, of course, on overlap and on ground control, and point transfer. The resulting accuracy, after block-adjustment, can reach values of two to four microns. Such accuracy is practically independent of photo scale. It is expected to hold at 1:50 000 photo scale in the same way as at 1:5 000 photo scale. In 1:5 000 photo scale four microns are equivalent to two centimeters in the terrain. In 1:25 000 four microns correspond to 10 cm. Such figures sketch the accuracy capability of photogrammetric point determination.

There is, however, one condition: Such accuracy results can only be reached if the identification of points is adequately accurate. Therefore, such accuracies can normally be reached only if the points are targeted and, of course, if the connections of photographs through tie-points are equally accurate. Under such conditions photogrammetry can reach, technically, almost any required accuracy for point determination, up to the limit of about 2 cm in the terrain, or even better. At very large photo scales there are problems with image motion and with signalization.

Besides the technical side, the real question, of course, is the economy of the method. Photogrammetric point determination has to compete with ground survey methods. Photogrammetry can have economic problems if, for instance, the densification of a trigonometric network to perhaps one point per square kilometer is required with an accuracy of 2 cm. In such a case the photogrammetric point determination may cost DM 500 per point or more. Whilst it may be just competitive with ground survey methods, the photogrammetric method for densification of geodetic networks remains ambiguous in Central Europe as geodesists have preferred to think in terms of 1 cm accuracy. In other countries, however, quite different situations prevail. I may refer, for instance, to a recent paper by D. C. Brown dealing with his tests in Atlanta City. There, about 1 point per square kilometer had to be established within a area of about 40 x 40 km^2. Brown figured out that under such circumstances photogrammetry can reach 5 cm accuracy from photos taken at the scale 1:17 500. The photogrammetric method is about three times as economical as comparable geodetic determinations. So photogrammetric densification of geodetic networks can be a highly economic method, the application of which is feasible in many cases.

There is one further point to be brought forward concerning photogrammetric densification of networks. Conventionally, we think in terms of a strictly separated hierarchy of trigonometric systems, of first to third or fourth order. After the fourth order we have the system of traverse points, and thereafter the cadastral boundary points. Photogrammetry has the unique possibility to combine the determination of several systems in one step, for instance the fourth order "trigonometric" system with the "traverse" system and the cadastral points. In such a combination the economic situation looks very much more favourable, as we have many points per photograph. Combining determination of low order trigonometric systems with cadastral points simultaneously is really recommendable wherever feasible, also for developing countries. It is technically possible, even with high accuracy requirements. Economically it is a sound system, highly competitive with ground survey methods.

Konecny

I think we can come back to these points in the session later on or would anyone care to immediately make a comment? I feel we should go right through the questions and at the end have a discussion.

Dubuisson

As far as the practical and theoretical accuracy limits of aerial photogrammetry in the densification of control networks are concerned, I have the following comments:

a) It should be noted that the generalization of analytical plotting has totally changed the answers to these questions, particularly regarding the following three possibilities:
   - tripling the accuracy as compared to analogue stereoplotters,
   - quintupling the setting speed for pairs of exposures,
   - immediate (30 seconds) resetting of a pair of exposures that were already oriented in a stereoplotter.
b) Under these conditions, the multiplication of pairs of exposures required for pictures taken at very large scales is no longer a hardship in photogrammetry. With the same accuracy, pictures may be taken henceforth at three times smaller scales. This upsets all well-established standards.
c) Principally, there is no theoretical and practical limit of photogrammetry at scales between 1/500 and 1/50 000.
d) The real limit to photogrammetry lies in the very nature of the orientation: the possibility of identifying – and thus plotting – only points visible on the pair of exposures. The excessive development of completion surveys may thus lead one to

prefer a ground survey, from both the safety and labor-saving points of view; the best example of this is the search for party-wall boundaries in urban regions.

e) The density of control networks is linked to the preceding problem and to the required accuracy. We are not unaware of the interesting work done by certain "Vermessungsämter" in Germany in combining ground and photogrammetric measurements for urban cadastres. On a whole, however, and for current operations, it may be estimated that a point density from 1 to 3 points per pair solves all problems. The specificity of each of these problems should be noted, however.

Konecny

Obviously the specifications are set for surveys by ground methods, which is one of the difficulties. Perhaps on the second point you don't still agree.

Grün

EFFICIENCY OF PHOTOGRAMMETRIC PRECISION METHODS FOR DENSIFICATION OF CONTROL NETWORKS

We all know that during the last 20 years a special branch of photogrammetry has been growing rapidly, which we call "analytical photogrammetry". It is typical, that analytical models can be made as rigorous and general as required. In addition, photogrammetric instruments such as comparators are accurate enough to allow the precise measurement of photogrammetric (observational) quantities. We may, therefore, speak of "precision methods".

And this is the current situation:

– Today, analytical photogrammetry has reached a standard of efficiency, which allows it to compete with the classical methods of terrestrial surveying even in the field of densification of control networks.

For the process of measurement 3 criteria are essential:
Reliability, Accuracy, Economy. Wherever photogrammetry is applied in practice, it is considered as a very economical method. We think that it can fulfil this claim in the field of cadastre and for the densification of control networks. However, a-priori conditions for this are at least a few hundred points to be determined, a highly operational computer program to exhaust all the photogrammetric accuracy potential, and an adequately trained team of collaborators. I am sure the problem of economy will be discussed later on, perhaps in Session V. So I want to turn your attention towards the problem of reliability. The term "reliability" has to be very strictly separated from the term "accuracy". A measuring system may be "accurate" without being "reliable" at all. We consider a system "not reliable", if there is a risk that one cannot detect gross errors or systematic errors in same of the points within a certain statistical likelihood.

Quite recently photogrammetric research has undertaken great efforts to stabilize the reliability of photogrammetric systems. Our strategy is to detect large gross errors before the main adjustment is done; we do this by automatic checks of the data and by special pre-adjustments with less expense.

I would now like to focus on the problem of accuracy. The small gross errors are then treated by statistical methods (after the main adjustment) as Baarda has shown.

An old Chinese saying tells us: "It is not enough to come to the river for catching fishes; you also need the fishing-net".

Related to our problems, this means: If we want to achieve the best accuracy, we need the most rigorous method. And this is, without any doubt, the bundle method rather than the method of independent models.

At our institute here in Munich we work with our bundle program MBOP (<u>M</u>unich <u>B</u>undle <u>O</u>rientation with Additional <u>P</u>arameters). This program satisfies a very important claim to a modern bundle solution: it is a self-calibrating program, i.e. simultaneously compensates systematic image errors. Systematic image errors, which can be interpreted as model errors, are introduced as additional parameters – i.e. additional unknowns – in the adjustment's observation equations.

With these additional parameters we are fully flexible; there is no fundamental restriction concerning their number and type.

In the following we shall see what importance the elimination of systematic errors has in practical projects, and to what extent the accuracy of the adjusted point coordinates can be increased. But first I will present some theoretical accuracy models of the bundle adjustment. Then I would like to check whether these theoretical models are achieved in practice.

The following theoretical accuracy studies belong to investigations, which will be published by Professor Ebner, Dr. Krack und Mr. Schubert. In these investigations, planimetry and height are treated separately, because they correlate only very slightly under usual geometric circumstances. We assume synthetic wide angle blocks with different block sizes and different control distributions.

The image coordinates are supposed to be uncorrelated and of equal accuracy; their standard deviation is denoted by σ_o. Figure II-2 shows the assumed planimetric control distributions; all blocks are of a quadratic form.

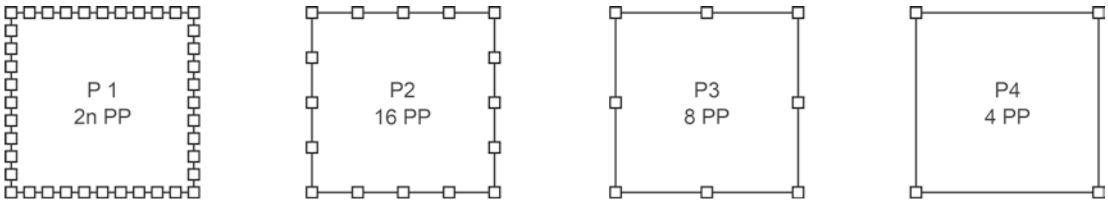


Figure II-2. Planimetric Control Distribution for 60% Forward Overlap and 20% or 60% Side Lap.

Figure II-3 shows the relationship of the mean standard deviations of the adjusted ground coordinates dependent upon control distribution and block size. μ_{xy} denotes the RMS value of the standard deviation of the adjusted planimetric ground coordinates x, y. To be independent of the image scale and the accuracy of the image coordinates, μ_{xy} is related to σ_o and m_b; n is the indication of the block size, e.g. n = 10, 20, 30, 40 base units in each direction.

Figure II-3a shows the results for 60% forward overlap and 20% side lap. Figure II-3b for 60% forward overlap and 60% side lap.

Now we have to state the most essential results of these investigations:
– For high-precision photogrammetry a relatively dense perimeter control distribution is necessary. However, in densification networks of third or fourth order, or in cadastral surveys dense perimeter control is usually available. Then, even for large blocks (20 x 41 = 820 photos) and with only 20% side lap.

$$\mu_{xy} \leq 1.5 \times \sigma_o \, m_b \,. \quad (i \leq 10b \text{ is considered})$$

To obtain a practical idea of this value, I would like to make the following assumptions:

$$m_b = 5000, \quad \sigma_o = 5\,\mu m.$$

Then,

$$\mu_{xy} \leq 1.5 \times 5 \times 5000 \mathrel{\widehat{=}} 3.8 \text{ cm}.$$

For cadastral purposes we even may presume a control distance of i = 2 baselengths

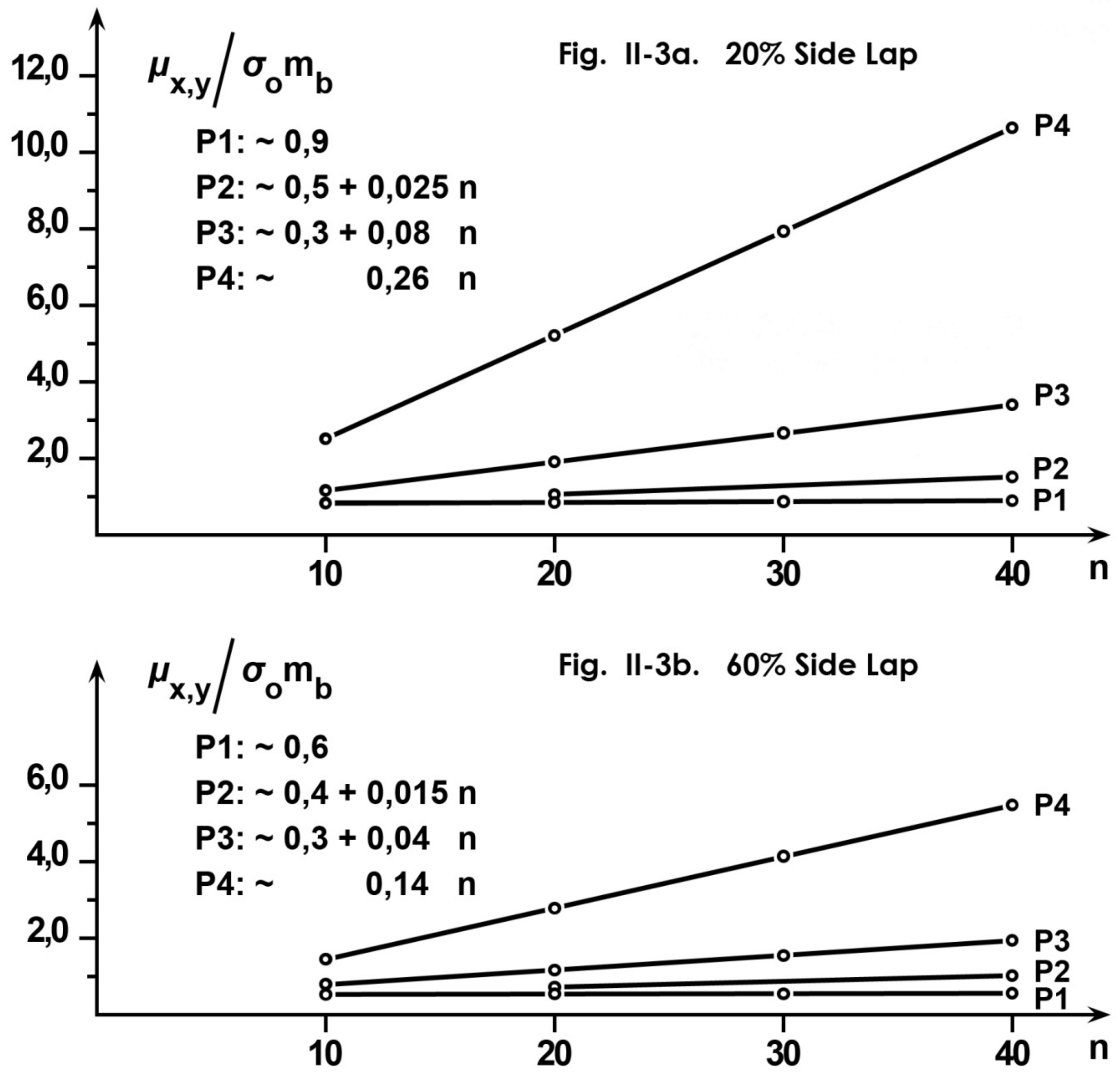


Figure II-3. Normalized Planimetric RMS Error vs. Blocksize for different Control Distributions.

or less; then for 20% sidelap we obtain

$$\mu_{xy} \leq 0.9 \times 5 \times 5000 \mathrel{\widehat{=}} 2.3 \text{ cm.}$$

This value decreases linearly with decreasing σ_o and with increasing photo scale.

Another result is the following:

– With dense planimetric control distribution the accuracy is improved by a factor 1.5 if 60% sidelap is used instead of 20% sidelap. At this point it must be emphasized that certain reliability criteria require the use of 60% sidelap. If the heights are of special importance, a sidelap of 60% is desirable in any case. The corresponding height accuracy models are related to a quadratic screen of height control.

The corresponding law of errors is as follows:

$$\mu_z \approx 0.32 \times i \times \sigma_o \times m_b .$$

i = Distance for height control in units of baselengths in x and y. With a height control spacing of less than 8 baselengths and 60% sidelap we may expect a mean standard deviation of

$$\mu_z \leq 2.6 \times \sigma_o \times m_b ,$$

which is practically independent of the block size. This means, with the previously used data:

$$\mu_z \leq 2.6 \times 5 \times 5000 \mathrel{\widehat{=}} 6.5 \text{ cm}.$$

Now we have to state that theoretical accuracy models yield a very essential limitation: They start from the hypothesis of random errors only. Our experience with the entire field of geodesy and surveying shows us again and again, that this is a risky, perhaps an inadmissible assumption. And we photogrammetrists especially are fully aware of this situation. Therefore, we are confronted with the decisive question: Are the just presented accuracy models of bundle adjustment transferrable to practical projects? This question can only be answered by practice itself. For that reason I would like to draw your attention to two practical projects; both are well-controlled photogrammetric blocks. First a controlled height block (Project Steinbergen), whose data I got for computation from the Niedersächsisches LVA. In Table II-1 we see both the block specifications and the results.

Table II-1. Photogrammetric Specifications and Results of the Project Steinbergen (Heights only).

CAMERA	ZEISS RMK A2 15/23 (WIDE ANGLE)
FORWARD OVERLAP	60 - 80%
SIDELAP	60%
NUMBER OF PHOTOGRAPHS	109
PHOTO SCALE M	1 : 8000
BRIDGING DISTANCE FOR HEIGHT CONTROL ..	1 ~ 3.5 B
NUMBER OF HEIGHT CHECK POINTS	55 (DETERMINED BY LEVELLING)

PARAMETER VERSION	σ_o [μm]	PRACTICAL ACCURACY μ_z [μm / cm]	APPROXIMATE THEORETICAL ACCURACY μ_z [μm / cm]
WITHOUT ADDITIONAL PARAMETERS	5.6	14.3 11.4	5.9 4.8
BLOCKINVARIANT ADDITIONAL PARAMETERS	5.4	8.0 6.4	–

μ_z ... RMS VALUE OF THE RESIDUALS AT HEIGHT CHECK POINTS

We notice that the theoretical accuracy expectations are not met completely even if additional parameters are included. The reasons for this are that there are

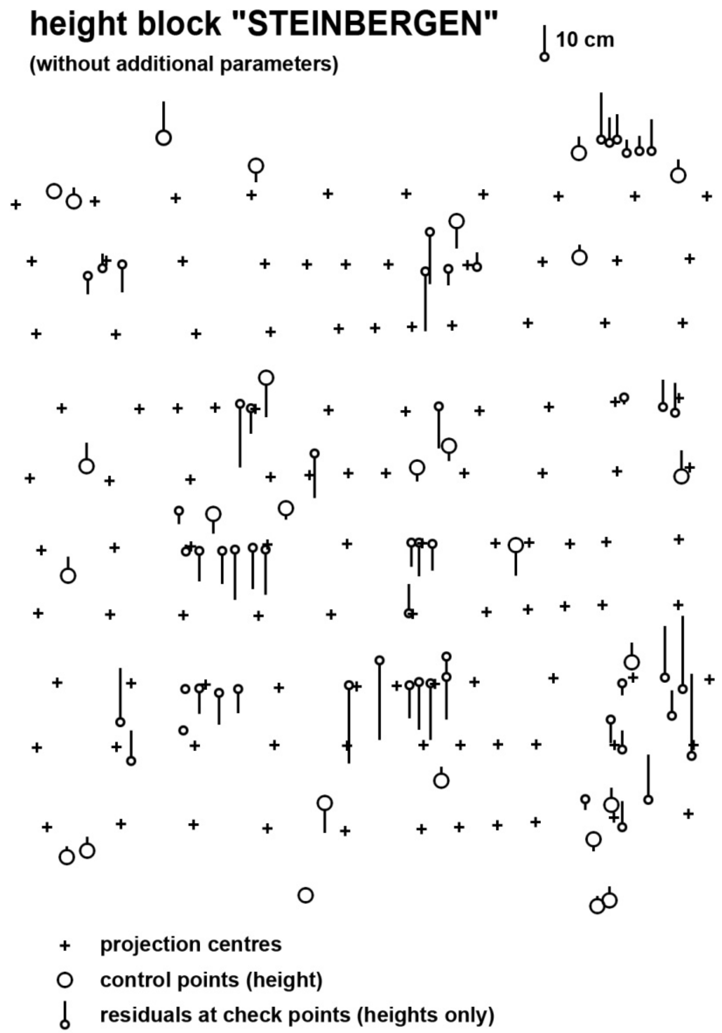


Figure II-4a. **Plot of Height Residuals after Adjustment without Additional Parameters.**

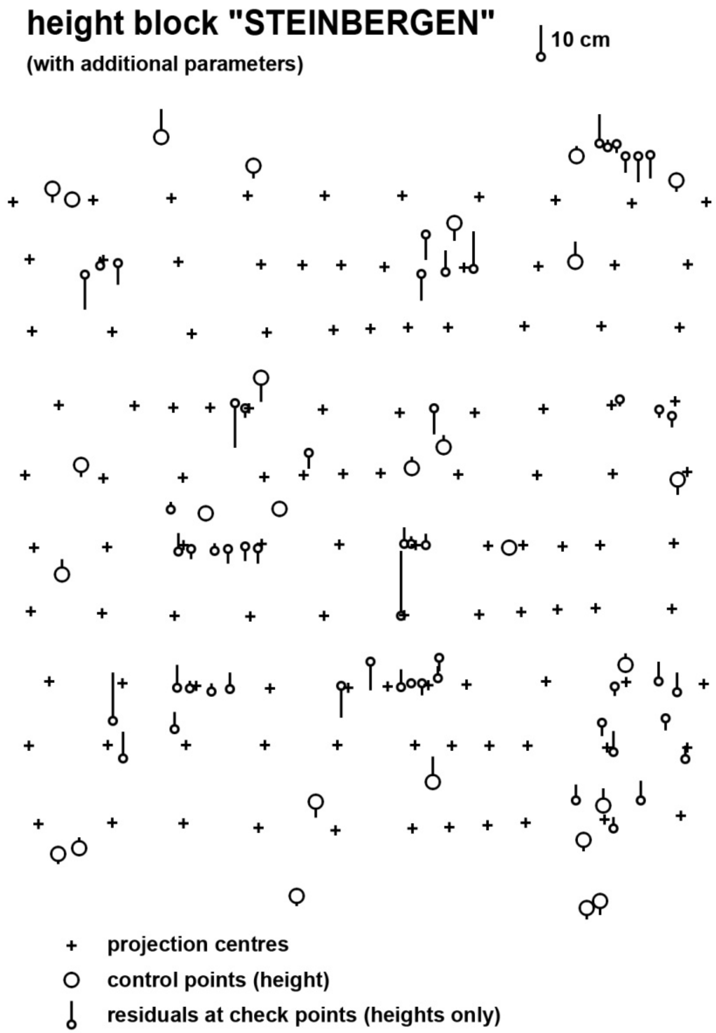


Figure II-4b. **Plot of Height Residuals after Adjustment with Block InvariantAdditional Parameters.**

different conditions in theory and in practical tests; also we have to take into account small, so-called "local" and "regional" systematic errors, which are changing perhaps from image to image and consequently are not eliminated by adjustment. anyhow, we are allowed to state that the use of block-invariant additional parameters resulted in a very remarkable improvement of accuracy (factor 1.8). Moreover, we have to notice the high accuracy level of the adjusted heights.

I am sure that these 8 μm in the photo scale, i.e. 6.4 cm at the object, may satisfy even excessive topographic accuracy expectations. The following figures (Fig. II-4a, II-4b) show plots of the residuals at check points. After elimination of the block-invariant systematic errors the residuals are more or less randomly distributed.

The second example is a well-controlled cadastral block of the Suburb Moosach near Munich. I computed this project with our bundle program for the Bayerisches LVA. In Table II-2 we see the specifications and the results.

Table II-2. Photogrammetric Specifications and Results of the Project Moosach (Planimetry only).

CAMERA	ZEISS RMK A 30/23 (NORMAL ANGLE)
FORWARD OVERLAP	60%
SIDELAP	60%
NUMBER OF PHOTOGRAPHS	93
PHOTO SCALE M	1 : 3300
BRIDGING DISTANCE FOR HEIGHT CONTROL ..	I 2 B
NUMBER OF PLANIMETRIC CONTROL POINTS ..	25
NUMBER OF PLANIMETRIC CHECK POINTS	133

PARAMETER VERSION	σ_o [μm]	PRACTICAL ACCURACY μ_{xy} $\begin{bmatrix}\mu m\\ cm\end{bmatrix}$	APPROXIMATE THEORETICAL ACCURACY μ_{xy} $\begin{bmatrix}\mu m\\ cm\end{bmatrix}$
WITHOUT ADDITIONAL PARAMETERS	5.0	10.6 3.5	2.4 0.8
BLOCKINVARIANT ADDITIONAL PARAMETERS	4.2	5.1 1.7	–

μ_{xy} ... RMS VALUE OF THE RESIDUALS AT PLANIMETRIC CHECK POINTS

Again a very high accuracy level was reached. A checked standard deviation of μ_{xy} = 1.7 cm must be considered as very satisfactory, even for European claims for cadastral networks.

What we further recognize is the considerable improvement with a factor 2.1 achieved by the method of self-calibration. But there is still a significant difference to the theoretical value of 1.0 cm. How can this be explained?

Let us look at the next plots which show the residuals at the planimetric check points (Fig. II-5a and II-5b). First to Figure II-5a. Here we see the situation without using additional parameters and hence we notice remarkable systematic tendencies. Figure II-5b shows the residuals after compensating for the block-invariant systematic image errors.

On the perimeter we find mostly random effects. But in the points marked by black dots a clear systematic tendency is visible. If we try to search for these facts we find out that these points were observed as points of same traverses which were only simply connected to the existing net.

We may conclude from this that the systematic tendency can be attributed with great probability to the geodetic point determination; by this we may partly explain the difference between the theoretically expected and the practically achieved value:

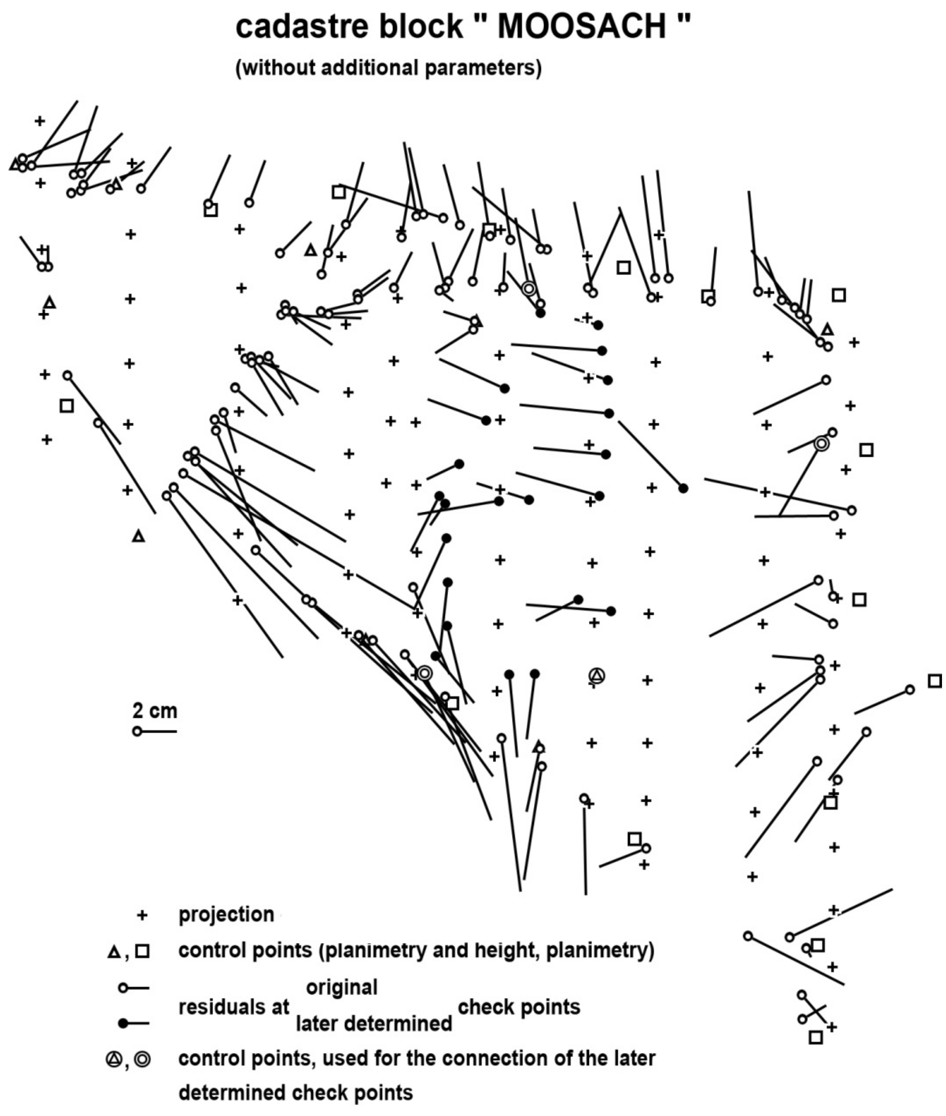


Figure II-5a. Plot of Planimetric Residuals after Adjustment without Additional Parameters.

– On this very high accuracy level (1-2 cm) we can be sure that the random accuracy of the geodetically determined control and check points have a significant influence.

At this point we must state the bounds of photogrammetry: in general practical cases photogrammetric results will not be better than the geodetic control points used.

Summarizing the results we may say:

1. With modern methods of analytical photogrammetry, especially when applying the concept of self-calibration, we are able to achieve an accuracy level with makes photogrammetry competitive as an independent procedure for densification of control networks and for cadastral purposes.
2. As well, photogrammetric methods are very economical, in particular if the photographs are further used for plotting or planning purposes.

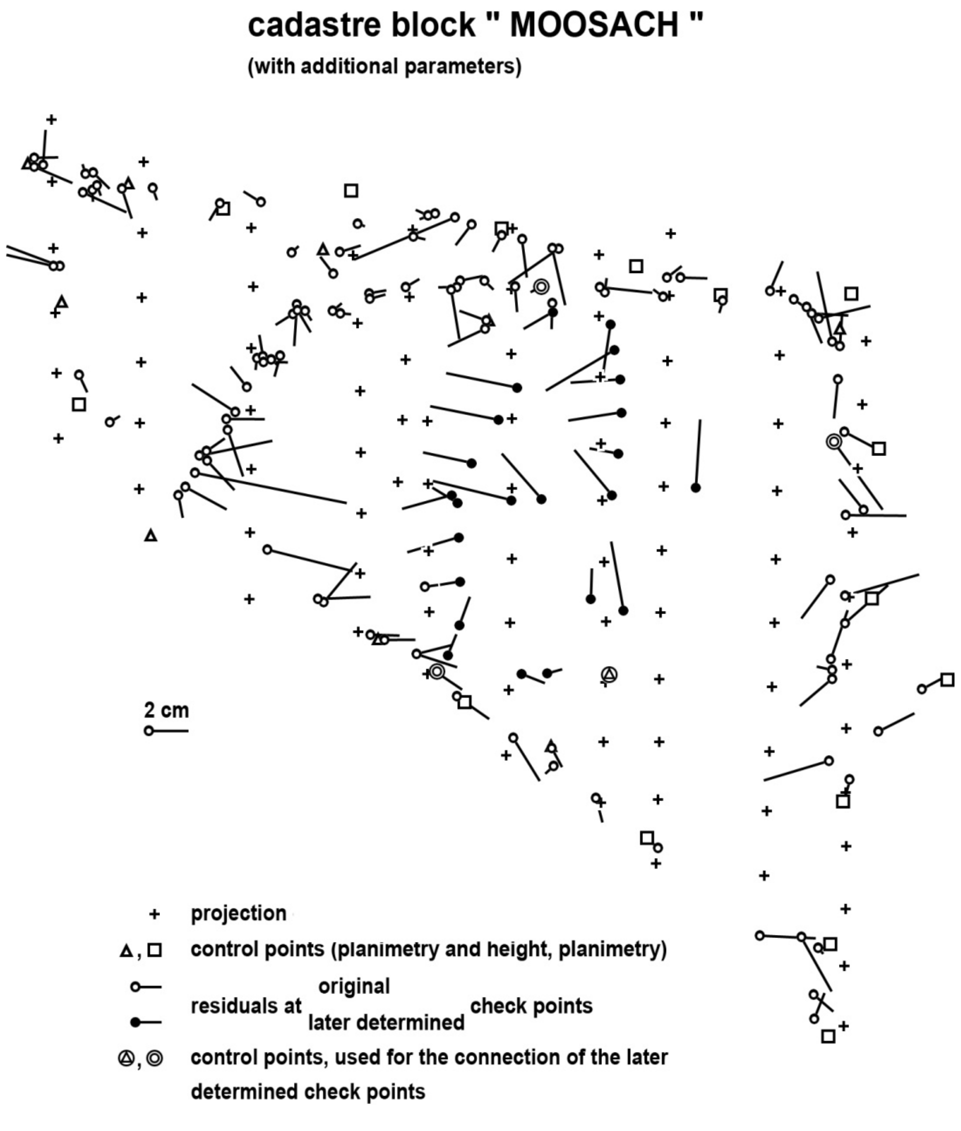


Figure II-5b. Plot of Planimetric Residuals after Adjustment with Additional Block-Invariant Parameters.

I hope and I believe that the future will show that modern analytical photogrammetry becomes an indispensable procedure for purposes of densification of control networks even in the case of very high accuracy requirements.

Konecny

We have had an excellent illustration as to what photogrammetry is capable of. Now I would like to begin the discussion on this point, followed by a discussion on the question of economy.

Van Twembeke

For more than 15 years we have used in Belgium numerical photogrammetry in the reallotment department. Until now the surveyors have not accepted <u>two different coordinates for the same physical point</u> in the field. This problem is caused by the fact that the Belgium cadastre is responsible for the framework of control points fixed by the classical topographic method. After the block readjustment we find for these control points coordinate differences of 2, 3 or even 4 cm.

The cadastre will not accept these differences, and for this reason the reallotment department has developed a special transformation theory, named the <u>"anamorphotic transformation"</u>. This transformation method can be defined as follows: In a plane are given the values U_1, U_2, ... of the quantity U in the points A_1, A_2 ..... . This collection of points constitutes a number of lines forming a unique contour.

Now one is asked to calculate the value of the quantity U in other points P of the plane.

The object of the transformation is to eliminate the differences between the two types of coordinates. Suppose I - 1, I, I + 1 are the control points in the <u>geodetic system</u> of the cadastre. Suppose i - 1, i, i + 1 are the corresponding points after the block readjustment and transformation in the <u>photogrammetric system</u>. Suppose "j" represents any point of the second system (Fig. II-6). The vector displacement, $\bar{\delta}_j$, of the point j is given by the formula:

$$\bar{\delta}_j = \frac{\sum_{i=1}^{N}\left(\tan\frac{\alpha_{i-1}}{2} + \tan\frac{\alpha_i}{2}\right)\frac{\bar{\Delta}_i}{d_i}}{\sum_{i=1}^{N}\left(\tan\frac{\alpha_{i-1}}{2} + \tan\frac{\alpha_i}{2}\right)\frac{1}{d_i}}$$

More details on the transformation method may be found in the publication by: U. Van Twembeke et E. Lievens: "Le plan topographique obtenu par anamorphose" in Bull. trimestriel de la Société Belge de Photogrammétrie, no. 119-120, Sept.-Dec. 1975.

Konecny

Thank you very much. I think this is of concern and one of the major drawbacks in defining analytical photogrammetry, because it simply points out that there are errors on the ground. I am glad that you raised that point. The question

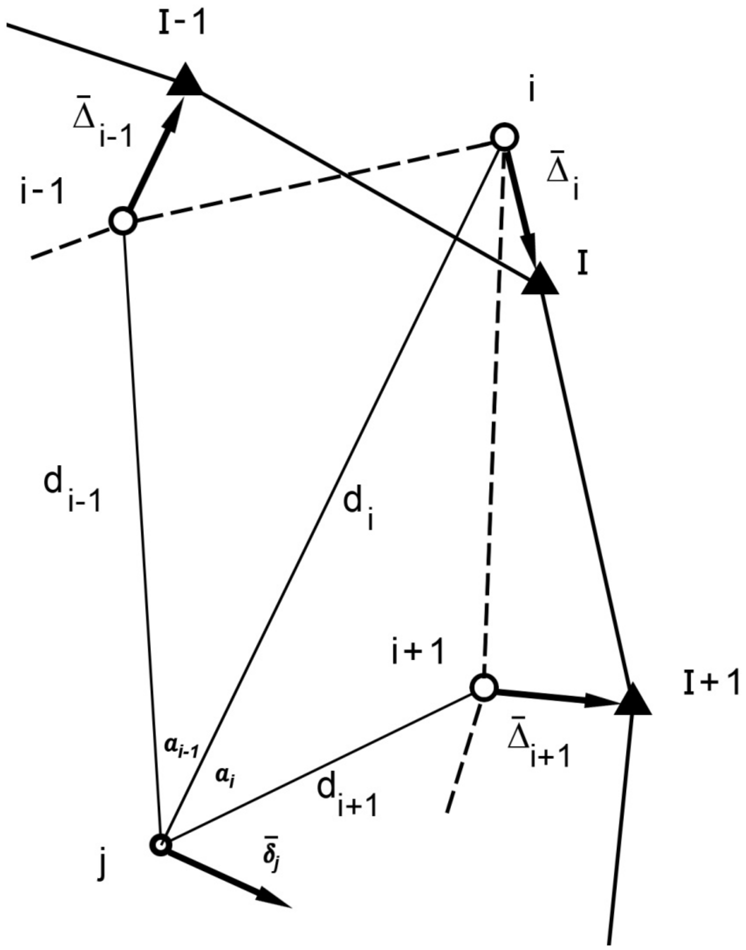


Figure II-6. Anamorphotic Transformation.

whether to resurvey a certain area by photogrammetric means is really worthwhile to be considered.

I think that two of some of the questions that were raised by the panel members might be of particular interest. Professor Ackermann mentioned that the linear accuracy is somewhat in the order of 2 cm and theoretically we can go down to 1 cm. I remember one of the publications that has been conducted by the survey of the railway station in Darmstadt, viz. in a dissertation of Professor Deker's group. It was found that at a scale of 1:1500 a practical accuracy could be reached, limited only by the setting of points. So if one really wants to, one can get such high accuracies. It is then a question of economy. Again I would like to simply come to the signalization. We have seen that for the signalization procedure as such we have a maintain the signals on the survey points. 40% of the cost goes to signalization, therefore we might as well choose the signals to *define* the boundary markers. The problem of maintenance would then have to be absorbed outside of photogrammetry.

These were my few remarks.

Grün

This is the problem if you want to get such an accuracy; i.e. a problem of the identification of the target.

Ackermann

I realize that the accuracy of 2 cm represents a practical limit under ordinary photogrammetric circumstances. Accuracies of 1 cm or better are obtainable, however they require very large photo scales of 1:2000 or larger. Long focal distances are used, or even helicopters may be needed. There are successful examples of special applications with extreme accuracy, as for instance the photogrammetric survey of railway station areas. In such cases the screw of the rails are targeted with little plastic caps. The resulting accuracy with photo scales around 1:2 000 is in the order of 1 cm. Apart from such applications with special conditions photoscales of 1:3 000 or 1:4 000 and 2 cm accuracy represent a practical limit for routine air survey methods, with ordinary type of targets. It is true that the economic problem of photogrammetric point determination is really a function of the signal station of the terrain points. Almost half of the cost of the total project goes into signalization.

It would be really a major economical step forward if we could eliminate targets in one way or another. There are certain possibilities; one is the application of the largest possible photo scales, such that boundary points can be seen directly without previous targeting. Also some modern type of boundary markers have a permanent white target on top. In this way special signalization efforts may be avoided. Nevertheless a general solution has not been found yet. Signalization remains, for the time being, a major practical problem.

Waldhäusl

We have also another problem: the points that we determine with our new accurate methods, such as bundle or model block adjustment, move on the terrain. Traffic, earthworks, soil cultivation, ploughing, earthquakes, avalanches, landslides, frost, water, roots of trees, the slow downhill movements of the soil – all may bring about point movements. Even forests move downhill, what we learn from those trees is that they do not grow straight up, but show the form of a Turkish sword.

After 10 or 50 years, networks are altered physically. The order of magnitude of the changes I speak of is about 3 to 10 cm between 350 m network points. In mountainous terrain, it may be greater. Therefore we need not be more accurate than the object network's stability allows for.

Konecny

Thank you for the comment. Now we shall go to the question number three: <u>of-line or on-line production of numerical maps?</u>

Dubuisson

<u>Production of numerical maps off-line or on-line.</u>

I shall examine three production phases:

a) Simultaneous or pseudo-simultaneous, sequential and fragmental checking of each recording sequence. This may be performed on the stereoplotter drawing table or on an interactive CRT-display. It must permit immediate corrections, but it does not imply thematic expression of the "code" of the recorded object. This is an operation which may be considered as on-line.
b) Overall, detailed checks of the recordings of a pair of exposures and its matching with adjacent pairs. This operation is obligatorily "off-line" on an interactive console with direct action on the primary data magnetic tape. This operation is off-line because it is not necessary to stop a stereoplotter in order to carry it out.
c) Subsequent processing is also obligatorily off-line and consists in territorial readjustments of areas surveyed by photogrammetric pairs of exposures to transform them into cutoff areas for the edition of maps; it is also suitable for creating magnetic storage of the "drawing system" by injecting the thematic representation system of features coded during the acquisition phase.

In summing up, an off-line cartographic system linked to a computer is a dangerous way of thinking even with the most advanced technological means such as analytic stereoplotters and interactive consoles, for it is incapable of compensating for inevitable human failures. In reality, the true problem is not whether or not one should work off-line or on-line, but rather the organization of computer files between purely numerical measurements of plots and data related to objects which they represent. Two roles are in conflict with this subject. This involves "recording formats", directly linked to further compilation and "updating" problems. Finally, all these problems are easily solved by <u>Analytical Stereo Plotters</u> which allows various configurations during the development.

We know that the universal stereoplotting instrument, in principle analog, which is capable of satisfying all the requirements of a survey, is a myth which has been abandoned in our days. Suddenly, the 1976 Helsinki Congress demonstrated that this line of photogrammetric evolution had been abruptly interrupted by the appearance of many analytical photogrammetric systems which have become effectively of plotting.

It is well-known that the only real problem with an analogue stereoplotting instrument is that of relative orientation, not absolute orientation. The whole question of accuracy lies in this operation, whether in aerotriangulation or in any form of plotting.

The problem disappears entirely in analytical photogrammetry, as it is solved by the computer with an accuracy three times greater, and in a few seconds by using an as great number of points as one wishes (e.g. forty for a pair of exposures in the French analytical stereoplotter Traster). The flow of information of this operation is the following:

A. ACQUISITION of image coordinates in both images of a stereo pair, for n ($5 \leq n \leq 40$) relative orientation points. Interior orientation parameters known. Typical standard errors are 1.5 µm.
B. COMPUTATIONS: Overall iterative calculations within a few seconds of time.
   (1) Coplanarity matrices for all relative orientation points. If $n = 5$: Spatial intersection of model points; if $n > 5$: Least squares spatial intersection for model points; model coordinates defined by bisecting minimum distance between homologous rays: X_i points – Initial rotations R_1 and R_2.

(2) "Return" calculations of image coordinates for both images from inverse vectors connecting model points found in (1) and perspective centers.
(3) The discrepancies between directly measured image coordinates and those obtained in (2) are processed by a least squares adjustment; calculation of optimal values of dX_i, dR_1, dR_2.
(4) Reiteration of the processes (1), (2), (3).
(5) If image coordinate discrepancies are less than a predetermined threshold value, stop iteration. Display results on CRT, included plots for error vectors; store stereo model parameters in memory.

C. STEREO MODEL: With an accuracy of 4 to 5 µm, i.e. an accuracy increase factor of 3.5 as compared to analog stereoplotter results, and this obtained in one-fifth of the time. Keyboard control of slaving of correlation of the two pictures assuring automatic cancellation of parallaxes. End of operation.

Having described the fundamental principle of model shaping, let us now see how this can be introduced into the overall data-processed orientation routines. It should be pointed out, however, that the operator receives all successive operating instruction "spelled out" on a console's conversational tube (CRT); any eventual erronious action is immediately signalled. The result is an "intellectual comfort" for the operator, a factor which should not be underestimated.

The entire flow of information of all phases of the analytical orientation is the following (duration: 12 minutes):

1. Interior Orientation
   Measurement of fiducial marks
   Parameters introduced via keyboard:
   a) For each photograph:
      – distances between fiducial marks
      – focal length
      – elements of lens distortion
   b) For each pair of photographs, or for whole mission, either:
      – earth curvature
      – atmospheric refraction
      or:
      – parameters for various media through which the imaging rays have passed.
2. Relative Orientation and formation of stereo model
   (see above)
3. Absolute Orientation
   Alternatively for all control points:
   – measurement of model coordinates
   – introduction of ground coordinates via key board
   Computation of the parameters of absolute orientation and automatic servo control of pictures
   CRT display of coordinate residual
   If results are satisfactory, storage of final orientation parameters.
   End of operation.
4. Instrument ready for stereo compilation.

The adaptation of the generated analytical model to an existing cartographic base, put on the plotting table, does not need any translation, rotation or scaling of the map itself; this is done by the computer, after pointing to a few basic points.

In aerotriangulation, a new procedure adapted to the analytical plotter can by carried out which will save the time generally spent previously for measuring, selecting and identifying junction points. This results in the possibility of automatically driving the floating mark to the neighborhood of points that were already taken in previous photographic pairs.

The plotting of details, strictly speaking, may be expressed in the three customary forms: graphical, digital and orthophoto-topographical.

Graphical plotting is performed in a plane of reference programmed by directly controlling the plotting table by the computer. This graphical plotting may be accompanied, however, by digital plotting by simply connecting addressable or sequential magnetic storage units to the computer. This is the most important prerequisite for the purposes of integrated surveying and mapping systems.

Analytical stereoplotters permit the organisation and performance of rigorous orthophotography with lateral rectification of plotted strips in the most rational manner. The servo operations require knowledge of both the orthogonal ground coordinates of the corresponding points of contiguous initial scanning strips, and those of the image points in the plane of the orthophoto exposure. All this information is stored in memories. Scanning performed prior to this orthophotography may also supply data required for the "digital terrain model" and for the ultimate drawing of corresponding contour lines.

This summarizing review of possibilities is far being exhaustive of the "what for" of analytical stereoplotting. It demonstrates, however, in an obvious manner that this principle succeeds in achieving a synthesis of all possibilities of expression, especially for integrated systems.

Konecny

Thank you very much. I think the acclamation proves that first you have contributed an essential point to our question and secondly that you have managed within your allotted time to add some very valuable comments on the analytical plotter. Some of us here having dealt with this system for some time are glad to hear of the increasing interest in the analytical plotter amongst photogrammetrists.

To the topic: Dr. Grün has told me that he has no particular comments.

Ackermann

To some extent I can agree with the way of thinking just presented. However, a number of concepts need clarification. For instance, the term "off-line digital map" is not sufficiently clear in itself. The term "off-line" has many aspects to distinguish between digital mapping and a digital map. Computer assisted plotting produces a fair drawing through an intermediate, real-time, digital phase. The digital data are not kept, however. The result is a graphical plot, not a digital map. The term digital map is not accepted at all by some cartographers. In my opinion it can be used for describing the digital storage information, suited and ready for plotting. The graphical plot is merely a display of the digital map. The off-line production of digital maps reduces the photogrammetric plotter to a digitizing instrument. Coding and off-line manipulation of the data produce the digital map which can be plotted with an automatic plotter. Such a system of off-line digital mapping is, for instance, applied for large scale engineering maps in the Netherlands, and it seems to work very well. The difficulty is that such off-line production needs a very rigid system of operation in order to be successful. Therefore, there is a tendency to give the operator interactive control over the digital manipulation of the data. It means getting away from the rigid off-line principle. Personally, I realize the necessity for sufficient on-line control during the digitizing stage. However, I am not really satisfied with the present state of the interactive plotting systems. In my opinion the major steps of producing digital maps must be off-line. In any case, the conceptual system of digital mapping should be pushed further leading eventually to an off-line system including efficient checks during the data acquisition.

Konecny

I do not consider that there is a conflict of interests between the members of the workshop concerning this question. I think we particularly pointed out the advantage of aerial triangulation in creating e.g. the orientation data and the correction data in order to see what happens in the adjustment process from one model to another. Then it might be a difficulty in systems not comprising analytical plotters.

Dubuisson

I think one has to consider two stages of control after the compilation of geometric information and its digitization. The first one is to ensure that no points of functions are missing. The second control concerns the definitive or final plot. Really, the interactions between the observer and the system are of a different urgence in order to generate the topographic or thematic map. The first control stage must be on-line, the second one is to be off-line.

Andris

The question about off-line and on-line is important. It is a question of economics if you go on-line or off-line. With a lot of input data it would be practical to work off-line. For corrections and additional data it is efficient to use online working stations.

Konecny

Thank you very much. May I summarize roughly this session's topic? I think we have seen that photogrammetry in the words of Professor Ackermann and others is not the only method. We have also seen that any desired and reasonable accuracy may be achieved by photogrammetry for purposes that were discussed. Then it merely remains a question of economy, simply meaning that the number of points per model is the deciding factor. Also the type of instrumentation – analog or analytical plotter – has a considerable influence on economy.

This concludes Session II.

SESSION III

FIELD SURVEY STANDARDS FOR INTEGRATED SURVEY SYSTEMS

Moderator	A. Chrzanowski (Canada)
Panelists	R. Adler (Israel) J. Polman (Netherlands) H. P. Spindler (Switzerland)
Discussants	H. R. Andris (Switzerland) F. Au (Germany) B. Dubuisson (France) H. Ebner (Germany) S. W. Kuranchie (Netherlands) J. McLaughlin (Canada) O. Neisecke (Germany) W. Tegeler (Germany) U. Van Twembeke (Belgium) P. Waldhäusl (Austria)

This session dealt with the following issues:

(1) What are the accuracy requirements of the integrated survey system?

(2) What is economically achievable accuracy of ground surveys in the densification of control networks and in detailed mapping?

(3) What criteria should be used as a basis for accuracy specifications?

(4) How should the technological progress in ground surveys and computing be accounted for in standards and specifications for control surveys and detail mapping?

S E S S I O N III

Chrzanowski

I would like to start this session with a discussion on the question: <u>what are the positional accuracy requirements of the integrated survey and mapping systems?</u> I am particularly interested in the requirements for the control networks since the control networks serve as a basis for the correlation and integration of positional and geometrical information on topography, infrastructure, tenure, etc. I would like to concentrate our discussion on the accuracy requirements in urban areas where the highest accuracies are required.

I recognize two users of integrated survey systems who are particularly interested in the high accuracy: the cadastral (property) surveyors and the engineering surveyors. Here, I would not include construction surveys of a special nature such as for instance, in bridge or tunnel constructions, where millimetre accuracies are frequently required. These surveys do not need to be a part of an integrated survey system because they serve only a local purpose. It would be a nuisance to maintain such a super-high accuracy of the whole city control network in order to satisfy a few special construction projects. A local survey network must be established for each special project and, later on, when the construction is ready it should be tied to the integrated system. Therefore, in my opinion, we should not take the accuracy requirements of the special construction surveys as a criteria for the accuracy requirements of an integrated system.

As far as the cadastral surveys are concerned the accuracy requirements for the control network depend on the type of the integrated system. There are many ways for providing the integration depending upon the available technology, manpower and local needs. One end of the spectrum is represented by the classical manual integration approach based entirely on large scale graphical maps correlated by the grid of a coordinate system. The maps are supplemented by files of geometrical descriptions containing the results of original surveys. In this approach the use and accuracy of the horizontal control are limited only by the requirements of the graphical maps. The eventual setting-out or relocation of some details in the field is satisfied either on the basis of measurements taken directly from the graphical maps or, more frequently, on the basis of original survey documents (numerical records) retrieved from files.

At the other end of the spectrum is a computerized integrated system based entirely on numerical maps in which positions and geometry of all the details are shown by their coordinates. In such a system the horizontal control is used both for positioning and for relocation procedures. Graphical displays may be also used, but they serve only for indexing of data or for providing an overview. Various combinations of these two extreme cases are of course possible. Due to the steadily increasing cost of manual labour and the decreasing cost of computerization, the systems entirely based on numerical mapping seem to be inevitable in the future, even in those areas in which, at the present time, the graphical integrated systems are successfully employed.

The accuracy requirements of the horizontal control besome much higher in the case of the purely numerical (computerized) systems because in the extreme case the coordinates replace all the field survey records becoming the only available description and evidence for relocating the mapped details, including property (cadastral) surveys. Therefore, in extreme cases, we may face the situation as shown in Fig. III-1; point P was originally positioned by tying it (Survey I), for instance, to control points A and B. Now after a certain period of time a relocation of the point may become necessary and then a new surveyor may be requested to reestablish the point P on the ground. The new survey (Survey II) if based only on coordinates may be tied to different control points, say points C and D. The relative positional accuracy of the control network becomes, therefore, very critical in that case.

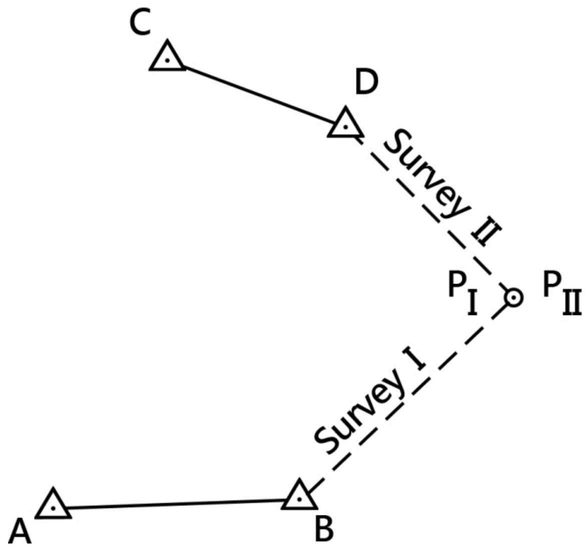


Fig. III-1. Relocation Survey Based on Coordinates.

Ideally, the relative positional accuracy of the control points in numerical information systems should be as high as it is technically feasible. This is not generally practical. In addition to economic concerns, there are certain limiting physical factors independent of the accuracy of surveying instruments which, even for the foreseeable future, may serve as constraints for the optimally accuracy. These limiting factors include: the instability of survey markers due to climatic changes and ground movements; the centering accuracy of survey instruments; and, the difficulty in physically identifying the mapped points.

A positional error in the order of 1 cm in terms of the semimajor axis of the standard error ellipse may be considered as a reasonable limiting accuracy for relocating a mapped point by using independent coordinate surveys. This corresponds to a tolerance limit of 25 mm at the 95% confidence level.

At this point I would like to mention that land surveyors in New York City, where the value of land is probably one of the highest in the world, claim half an inch, it means about 12 mm, accuracy requirement when relocating corners of properties.

The claimed accuracy is probably only an "internal" accuracy based on a comparison of original surveys with the remeasured distances between corners of the property. New York City does not have any coordinate system and all the survey records are kept by individual surveyors. Nobody can, therefore, check what accuracy do they really achieve until a possible quarrel arises between two surveyors entering each others "empires".

The aforementioned 2.5 cm limiting accuracy in relocation survey seems to be more reasonable in the case of integrated surveys. However, questions arise whether such a high accuracy is really needed and whether it can be achieved in an economical way when dealing with cases as illustrated in Fig. III-1. Perhaps a numerical system based on coordinates only is a nuisance?

Our study group in Canada has been involved in the above questions since two years in connection with a project in eastern regions (Maritime provinces) of Canada conducted by the Land Registration and Information Service (LRIS), a governmental agency. LRIS is involved in a development of a computer-supported land information system based on an integrated survey and mapping system. It also develops a system of, so-called, guaranteed boundaries in property surveys based on the geodetic control networks and on a full information on the accuracy of the location of the corners of boundaries. Many questions have to be answered before the system will fully operate; questions like:
- Does the control network in the Maritime provinces satisfy the requirements of the integrated survey system?
- Can the property surveys be based on the existing control and what accuracy in the relocation surveys can be achieved?
- What accuracy criteria should be adopted in the guaranteed boundary system?

Our study has not yet been completed but preliminary results have already been published by LRIS in a report: "Maritime Cadastral Accuracy Study" (March 1977). We shall send a copy of the report to those interested.

We have also made a study on the achievable accuracy of the control networks in urban areas. I shall come back to this topic later on. Now I would like to ask the panelists to give their comments on the accuracy requirements. We shall start with comments by Mr. Polman.

Polman

Yesterday I heard from Professor Konecny a very good definition of integrated survey and mapping systems as far as our country is concerned. He mentioned the combination of cadastral information systems, topographic information systems and information systems for utility works. With regard to the accuracy requirements I want to make a distinction between these three applications because the requirements are different.

The cadastral service in Holland started at the beginning of the 19th century with a cadastre for tax purposes. In the course of time not only the tax was important but also the protection of the rights on private property and the registration of the boundaries of cadastral parcels. For this purpose the measurements of new boundaries are recorded on field documents and the cadastral map is revised. These field documents can be regarded as the basic documents on cadastral boundaries. They are not only used for mapping but also for the reconstruction of boundaries in the field.

The accuracy requirements for reconstruction purposes are very high. These requirements are in our country based on the philosophy of Professor Baarda, viz. that a boundary should be registrated as accurately as it can be identified. So, boundaries, marked with stones, should be measured in a more accurate way than boundaries, which are not monumented, but marked by topographic features, such as fences and hedges. This philosophy means, that the relative precision between two well-marked points should be in the order of a few centimeters.

The accuracy requirements for large scale topographic maps are not as high as for cadastral purposes. In general it is sufficient to have an accuracy related to the graphic representation on the map. In practice the accuracy of measurements derived from a large scale map is in the order of 10-20 cm for the scale 1:1000. In a topographic databank this maximum accuracy can easily be realized with the registration of coordinates.

The same is valid for utility maps, that is to say the utility people are used to maps with relative measurements written on it. In a computer oriented utility network system this can be quite a problem.

In an integrated surveying and mapping system the accuracy requirements are in fact mainly defined by the requirements of the cadastral survey system. Therefore, only these requirements will be regarded in this presentation.

The main difference between a coordinate based cadastral system and a system based on field documents is that in the coordinate based system the original measurement on boundaries are thrown away. For reconstruction purposes the necessary measurements are derived from the coordinates. The problem is to maintain the required accuracy in a coordinate based cadastral system.

When establishing a coordinate based system in a certain area, a control network is constructed and on the basis of this network the detail measurements are carried out. After computation we get a very dense network of coordinated detail points. For the maintenance of this network it is necessary that the control network should be very dense and very homogeneous.

The density should be high, because the accuracy of setting out detail points from control points which are far away is too low. The homogeneity is important to make it possible to add new detail points to the existing point field with a reasonable relative accuracy.

Usually, a control network consists of a collection of points which are marked in the field, often under the ground. You have to search to find them and there is no guarantee that the point is not destroyed. The point marks remain in the ground for years and anything can happen to them in the meantime. This is one of the main problems in maintaining a minor control network.

In a coordinate based cadastral survey system another approach should be possible. The minor control points are only used for the realisation of the coordinate system in the field. For the maintenance of this coordinate system the detail points that can be identified easily and accurately and that will not be destroyed soon, can be used as the framework of the coordinate system. The corner points of buildings are especially useful in this respect.

In this approach in fact every house corner could be used as a control point. It only works if precautions are taken that existing points, used for a revision survey or reconstruction survey, are the same as the points used earlier.

You can only do that by checking these points with short distances. The short distances of today should be the same as the short distances measured earlier.

An important aspect of a coordinate based cadastral system is the reliability of the coordinates. The quality of the coordinate value is far less when they are influenced by gross errors. The detail survey should be set up in a way that statistical tests can be applied in order to detect the gross errors. It is important to make requirements for the size of errors that should be detected by the testing methods. In our country the requirements on the reliability of detail points depend on the interpretation accuracy.

The ideas on the precision and reliability of detail points are based on the interpretation accuracy shown in Table III-1.

Table III-1. Interpretation Accuracy.

class	interpretation accuracy	representative value k	meaning	examples
1	0 – 2 cm	1 cm	very good	control point, house corner, boundary stone
2	2 – 5 cm	3 cm	good	fence, wall
3	5 – 10 cm	7 cm	moderate	hedge, trench
4	> 10 cm	15 cm	bad	ditch

The interpretation accuracy of detail points is divided into classes. For every class a representative value is taken which is used in the computer programs.

The requirements on the control network should be based on the requirements for cadastral purposes. In reality we start from the existing triangulation network which was established some 50 or 100 years ago. We know something about the accuracy of this network which happens to be quite good. The precision of the triangulation points can be described with a covariance matrix. In practice we use an artificial replacement matrix. For a group of points this matrix is defined by:

$$\mathrm{diag}\,(d_1^2, d_2^2, \ldots, d_n^2)\,,$$

where the value of d_i^2 is computed through

$$(d_{i\ cm})^2 = c \cdot 1_{km} + (k_{i\ cm})^2 .$$

In this formula 1 is the average distance between the points in km, c is a parameter for the accuracy of the control network and k is the standard deviation of the interpretation of the detail point.

For the choice of this replacement matrix three assumptions are made. The first assumption is that there is no correlation between the points. The second assumption is that the relative precision of two points is proportional to the square of the distance between the points. The third assumption is, that the precision of a point is influenced by the interpretation accuracy of the point.

It appears that the artificial covariance matrix can be used for control points as well as detail points.

For the densification of the minor control network we use this replacement matrix, and, together with the precision of the measurements, we compute the precision of the new points by adjustment. As a criterion for the precision we use the same matrix as defined before. We accept the precision when the computed standard ellipses are smaller than the ellipses derived from the replacement matrix.

Simultaneously with the adjustment of the control network, we compute the reliability of the network because the reliability demands are far more than the precision demands. For the computations we use a computer program of the Technical University in Delft (SCAN) described in a presentation to the FIG Congress in Wiesbaden. In this paper you can see that, depending on the reliability demands, the construction of the densification network can be planned.

Chrzanowski

Thank you very much. Are there any immediate questions for Mr. Polman concerning his presentation?

Tegeler

I do not believe that the covariances are zero, because the detail points were surveyed and determined with the same methods and at the same time. I would think there is a high correlation.

Polman

Yes, that is true. I can say that the SCAN program I talked about does not use the matrix which I showed in my paper, but another replacement matrix which also gives the correlation between two points. The matrix I have shown you has been used for more than twenty years in our country, because it is a very useful, easy-to-use matrix. The more sophisticated matrix has been used for some years in the establishment of large control networks. It can only be handled with complicated programs on large computers. For the purpose of detail point networks we need a simple matrix. We think that this diagonal matrix is sufficient for detail work.

On the other hand, we think it is almost impossible to describe the correlation between detail points established at different times. From a practical point of view, we therefore have chosen the very simple matrix as described above. I think for control networks you should use a better replacement matrix.

Chrzanowski

Could I ask Mr. Spindler to give his comments on the accuracy requirements?

Spindler (translated from German)

I only would like to add a few principal ideas to the point. A group of surveying specialists, as has been assembled here, has a somewhat one-sided view considering accuracy requirements. I believe one should, in order to conclusively answer these questions, consult more groups, particularly the end-user, e.g. utility surveys, electric power plants, water works, gas works. The surveying specialists tend to specify as accuracy requirements that measure which is achievable. We shall be discussing, I hope, in the next question, what can actually be accomplished by today's terrestrial methods. I just believe that the surveying specialist will always approach the limits of the achievable, and define that as the requirement. An example has been given by Dr. Chrzanowski himself: this 1/2 inch, I believe, is not demanded by the property owner. To my mind he certainly is influenced by the surveyor, and this specification typically cannot be verified by anybody else but the surveyor himself. I thus believe that really unbiased end-users should be consulted.

There is also the danger when the user returns the question to the surveyor. If we just ask, e.g., the director of an electric power station, how precisely he must have his transmission line in the plan, or in his measurements, he then will say that is a problem for the surveyor, the surveyor should determine that. This danger exists, of course. I believe that one has to keep asking questions, trying to probe where the accuracy limit lies, where actually something will happen, i.e. where the accuracies influence accidents or large costs in the near future.

I find the English measuring system offering a reasonable dimension with its basic units, "inch" and "foot". I would consider <u>one inch</u> as reasonable for the base map, the base plan, provided for the <u>real estate cadastre</u> by the surveyor. For derived surveys, particularly for the underground utility cadastre, in my opinion the order of magnitude "one foot" is sufficient by all means.

Finally, one may still consider if one does not advance further by considering logical relations rather than by specifying a high accuracy for the untility cadastre. E.g., in general it is certainly true that a power transmission line or a water pipe line by no means may pass through the ground-plan of a building. We may perhaps accomplish more with such logical conditions that generally demanding the accuracy within the centimeter for purposes of the utility cadastre.

Chrzanowski

In summary, then, I understand that you agreed to accuracy requirements for cadastral surveys in urban areas to be in the order of 2 or 3 cm?

Spindler

That is correct.

Chrzanowski

Would you like, Dr. Adler, to add some comments regarding the question of accuracy requirements?

Adler

Very briefly, regarding yesterday's discussion, Professor Ackermann might agree if I say that the accuracy of the photogrammetric location of points is to be achieved at a level better than centimeters. I think that this is a more than feasible accuracy for important points of detail and for the minor survey control. What worries me is, as I said yesterday, that we would have to switch over to coordinates as the definition of points defining the boundary but I see that Mr. Spindler, at least in the English translation, thinks that the most important aspect is the life of the survey data of the cadastral system. I think that every survey organization has in its archives a lot of field books which were once plotted as cadastral plans and which are never going to be computed digitally. Therefore, we have to consider the question of digitizing the coordinates from the existing cadastral plans considering that they were surveyed within common control system and plotted with a great deal of precision. I think that people used the plot much better in the old days than they do it today. And perhaps we will have to compromise between what can be achieved by a direct survey and what can be extracted from the existing documents, because we cannot assume that from today we are going to have a new cadastral system and whatever is existing is just going to be ignored. I think that this is one of the problems that I would like to hear other comments on.

Chrzanowski

Now I would like to invite comments from the floor.

Neisecke (translated from German)

I may point out that we in Germany at one time adhered to the advisory board's "limit of error" ("Beirats-Fehlergrenze") for cadastral surveys, and after that the limit of error has been reconciled with the individual federal states. For example, Niedersachsen adopted 6 cm as its lowest error limit. These 6 cm are always admitted. However, if we have different measurements, then the lowest error limit already lies at 9 cm for a short distance up to 3 m. If the distance is enlarged to 6 or 7 m, we have already 10 cm. And so on. One third of this measure of 6 or 9 cm would have to be considered as the standard error, i.e. 2 or 3 cm. I believe we achieve that today by photogrammetry.

Van Twembeke

I agree completely with Dr. Adler; practically it is not possible to start a new survey of the whole country in order to get an accuracy of 1 cm. If you wish, you can have it, but don't forget: "you have just to pay for it". At this moment many of our countries have some graphical documents dating back 50 or 100 years, and most of them don't have a numerical background. Now, we have to adjust these documents in a first phase in order to pass on to numerical cartography by numerisation in a second phase. If we start now with new measurements, once more we need 50 years to reach a full numerical solution.

Chrzanowski

I agree with both statements. We should remember, however, that the purpose of our workshop is to organize an international study group which should give some guidance not only to the countries which already have an organized cadastre and an advanced integrated survey system but also to the countries which do not have any system and which have just started thinking about establishing one. We should advise them whether they should follow up the European model, it means to start organizing their system the way as it was done, say 100 years ago, or whether they should start organizing it in a new way talking into account the advantages of all the modern technology. They will be looking at our conclusions, looking for answers to the questions: should we use conventional ground surveys for the densification of the control, or aerotriangulation or the new inertial navigation methods? Which method is more economical and which method gives the sufficient accuracy? What accuracy is really needed in the integrated survey and mapping system? Should we start organizing immediately a numerical cadastre of graphical, or a combination of both?

We have to distinguish between the countries which are going to start organizing the integrated systems from scratch, from zero, and the countries which have already invested a lot of money and effort in establishing their survey and mapping systems and now they are thinking about a modernization of their existing systems. In the latter case it may be economically unwise and practically difficult to justify to the authorities a need for changes and modernization. The countries which are starting right now from zero have an advantage in this respect over the advanced countries. They may and they should employ the best methodology and the best possible technology in the new integrated systems. Can we, however, answer the question "what is the best methodology?".

Kuranchie

Mr. Chairman. I would like to contribute to the discussion by way of citing our experiences in cadastral surveys in Ghana. The survey regulations require that all survey work for cadastral purposes must be tied to national coordinated points. We depend on what is termed "Points of Departure" for checking the reliability and the stability of coordinated points before any new survey work can be based on them. Three coordinated points are necessary since this will make it possible to check both, the distances between the points and the included angle at the mid-point.

To this end distances between the points are first taped and compared with those computed from the given coordinates. The two sets of distances must agree within a certain tolerance depending on the length between the points. Secondly, the included angle at the mid-point is measured and also compared with the one deduced from bearings computed from the given coordinates. The two angles must also agree within a certain tolerance depending on the instrument used in measuring the angle.

Once these requirements are satisfied the points can be used as control points for the subsequent survey which should be executed by theodolite and steel tape traverse, unless the Director of Surveys directs otherwise. The minimum closing error or fractional misclosure for such a traverse is 1:3000 irrespective of the total distance of the traverse net. Using only two coordinated points means using the minimum since you can only check the distance between them and not the angle unless an azimuth is observed to check the bearing from the coordinates.

If we are to use photogrammetric methods for the densification of controls, then the coordinated points must be close enough for our purposes, or the points must be in groups of three. It is here that D. C. Brown's approach to the control densification by way of dual offset targeting appeals to us.

Chrzanowski

Thank you very much for your comments because they already give us some points for our discussion in Session V in which we shall discuss photogrammetry vs. ground surveys. We should also come back to your comments when we start a discussion on the question what criteria should be accepted for the accuracy checks whether as you say, the checks of the angles and the distances should be used or misclosures of traverses. Now I see that Dr. Dubuisson would like to make a comment.

Dubuisson

The emergence of means of measuring distances by very high precision electromagnetic processes creates a veritable dilemma. Inconsiderate use of possibilities offered by this accuracy leads to perfection-surveys four times more expensive than traditional surveys. Does one use his car at maximum load and speed capabilities? The real problem here is the following: Is this accuracy economically useful in our society? Is not speed sometimes more useful? At the risk of clashing with certain opinions, I should like to say that there is no reasonable significance in knowing the real-estate boundaries of a property with 1 cm accuracy. On the other hand, certain prefabrication or stability operations in civil engineering and public works benefit greatly from such accuracy.

In conclusion, there are no universal criteria for accuracy specifications; there are only common-sense solutions. It is nonetheless true that the various tables of tolerances for topometric operations published to date must be revised from both the point of view of stated accuracy and that of methodologies to which they apply.

Chrzanowski

Very true. Thank you very much. Any other comments on the accuracy-requirements?

Tegeler

Some comments regarding the utility surveys: If we have only one pipe or cable near a house this is no problem, but how can we solve the problem if there are many utility lines lying one upon another and side by side? I think that will be a problem and we must have a better accuracy. What accuracy, then, is necessary in that case?

Chrzanowski

Maybe, Mr. Spindler would like to answer.

Spindler (translated from German)

I think you have indicated the solution yourself. In such cases height specifications will be differentiated best. Planimetry, as I see it, does not play such a big role. It is just necessary to know that there is a utility line being located in this area of the street. When excavating the street, the line must be found. It is then above all important to know at what depth it appears.

Au

I want to point out again what Mr. Dubuisson said about the economy of the cadastral maps. For example, the relation between accuracy and cost. We might consider, for example in Niedersachsen where I come from, that a map sheet costs about 80,000 German marks from the start to the final presentation, which means from the survey work to the automatic plotting. So we should consider if the accuracy should be as high as mentioned here in this respect and I think if we come back to Mr. Adler's comment that we should look back into the old archives to look for the old measurements or the old surveys then we cannot meet the accuracy mentioned here of 1 or 2 cm. The scale of the maps which 1 mentioned above is 1:1,000 in the size of 50 by 60 cm.

Andris

In our country we have started a program to digitize existing cadastral maps in order to meet different requirements together with new surveys in an integrated surveying system. In such a system it is very important to include information about accuracy for each point. Our codes are the following:

1. very high precision obtained by triangulation
2. high precision obtained by traversing
3. mean of two or more measurements
4. one measurement with check
5. one measurement without check
6. digitized from scale 1:500
7. digitized from scale 1:1000
8. digitized from scale 1:2000

Thus, we can calculate tolerances as a function of the accuracy of each point and change the coordinates if we get better measurements of this point.

Chrzanowski

Of course, when we come to the discussion: What information should be connected with the coordinates then, obviously, if we would have the full covariance matrix for all the coordinated points then it would be the ideal solution. The question is, however, whether we are able to handle so many points to get the full information on the covariance matrix. In our projects in Canada we are advising to calculate the full covariance matrix. Of course, it requires a re-education program for the practising surveyors and the use of comparatively large computers. The individual surveyors will have to share the expenses of large computer centres so that they can use the facilities. We don't know yet how it will work in practice. Dr. McLaughlin will tell us a little more on our pilot project in Canada. I would like to give only a conclusion which resulted from one of my test projects in Canada concerning the accuracy requirements for a control network in urban areas. We accepted the aforementioned 25 mm at the 95% probability level as a tolerance for the repeatability of the relocation of the corners of the properties. We came to a conclusion that in order to obtain, according to the model drawn above (Fig. III-1), this accuracy of 25 mm we would have to have the density of the control points in urban areas in the order of 200 m with relative accuracies of 14 mm in terms of the semi major axes of the 95% relative error ellipses. It is a very high accuracy demand and as we have proved in the test project it is very difficult to achieve this accuracy in an economical way. Details of our test project on control surveys will be published in the September issue of the Canadian Surveyor. I shall send a copy of the paper to the participants of this Workshop.

We know from D. C. Brown's photogrammetry project in Atlanta City that they can obtain in an economical way the positional accuracy of 7 to 8 cm. It is a five times smaller accuracy than the aforementioned requirement of 14 mm as assumed in our test. In order to increase the accuracy from 7 cm to 14 mm one would probably have to increase the expenses of the control surveys more than five times, and it is a very basic question to be answered, from the economic point of view. What accuracy is really required? I think it is the basic problem when talking about the integrated survey systems. We nowadays can economically measure distances with a standard error in the order of a few millimetres over short ranges using the standard EDM equipment and angles with a standard deviation 1" to 2" employing standard techniques and, at a cost, we can achieve the positional accuracy of control points of the order of one centimetre. The question arises, however, whether the users of the integrated systems really need these accuracies? Maybe, the accuracy of 7 to 8 cm, as claimed by Brown, is sufficient for the densification control in urban areas? Maybe we are unnecessarily fighting for the millimetres. For example, in the city of Basel. They claim a relative accuracy of their control network to be of the order of 3 to 5 mm. But nobody could answer the question who really needed that high accuracy? So, it is like art for the sake of art. Yes, the surveyors would like to show that they can measure precisely. However, is anybody really using this high accuracy? And is it really needed? Maybe we can live with the 10 cm accuracy and nothing will happen, no catastrophy will happen, and then we could manifoldly decrease our costs.

Spindler (Translated from German)

Perhaps once more to these same considerations I can share an example that happened personally to me. We were renewing the 3rd and 4th order triangulation in the city of Zurich between 1970 and 1975. I myself had not been present during the starting phase – Thus being unable to exactly reconstruct the thoughts that were conducted at that time – but then I had the problem to later having to justify this project. We had had in the city surveys discrepancies in the range of decimetres. Now, we have reached, or slightly remained under, the centimetre range for the triangulation points. The politicians then asked why we needed this high accuracy, after all. I must admit that I had difficulties to plausibly explain it to them. I believe that we simply must keep in mind the real benefit of the survey, and should not indulge in academic exercises.

Adler

I think that we can live with the 10 cm accuracy and as Dr. Chrzanowski said, no catastrophy would happen. In Europe we have the best prove that for many tens and perhaps for hundred of years people have lived with a graphical cadastral accuracy which could be estimated at, let's say, 2 or 3 tenth of a millimetre of certain scale which was a function of the density of the population of the area and I think that it has proved itself throughout the years. So, if we are talking about the accuracy of the boundary points (I'm not talking about the control but the accuracy of the boundary points) then I think we have the proof that it has absolutely all the requirements.

Chrzanowski

So it means probably ten to fifteen cm.

Adler

Well, we could probably argue about this point but I would say 3/10 of a millimetre at the scale of the graphical map, which after all has always been a function of the character of the area. Mr. Au said just a few minutes ago 1:1000 for residential areas. This is very close to what we have in Israel for residential areas. We have 1:1250. Perhaps for populated agricultural areas 1:2500 and so on. I feel that the accuracy of the important details, e.g. boundary markers, are of concern to the user, and the figures quoted would be quite sufficient.

Chrzanowski

We should remember that in the old times when we used only the graphical cadastre we also used the field survey documents. Generally, when relocating a boundary you would use the graphical map plus the information from the old survey records, if possible. And then we would have at least the distances between the corners of properties from the old documents. Therefore, the real accuracy could still be kept higher than the graphical accuracy of the measurements taken from the map. Nowadays we are switching to computer assisted positional information which, in an extreme case, is limited only to the coordinates of the corners, which eventually will replace the system of graphical maps and survey records.

Adler

I feel that if we make a sequential analysis of what would have been a positional error of a point, then it would vary depending on which part of the traverse it was taken from. Those of us who spent some time in the field probably realize that the coordinates of detail points were always less accurate than their measured abcissae. So, I feel that when we were talking about digitizing existing points of graphical data then obviously we cannot take into consideration only the error of the digitizing process but also the error of the position of the point being surveyed.

Van Twembeke

My personal opinion is that imperfect information is better than incomplete information (or no information at all). In the case of developing countries it is unrealistic and impractical to start at zero on a numerical basis. A graphical document in the form of orthophotos is indespensable in the first 20 years, and this type of information will make the connection with a more numerical form of cartography in the future, if desired.

Chrzanowski

Yes, I agree, but the developing countries cannot and should not follow exactly the European models such as to go the same way as we started here 100 years ago. It would take them a too long time to catch up with the new developments. So, some compromise can and should be made. I agree that we should start with a graphical system in the developing countries and, later on, the updating of the system could be done in a numerical way.

Van Twembeke

That is my personal opinion. On the basis of existing information (graphical) we go over to a more complete system (numerical). But, don't forget, the user likes to examine a graphical document in all cases.

Neisecke (Translated from German)

The accuracy limit should depend on the value of the land, similarly as it is done in Switzerland. For urban areas, narrower error limits would be necessary than for rural or mountainous regions. The Swiss limits or error are specified in that manner. In my opinion, this is the characteristic where we must measure how high to assess the error limits. For, the parcel of land in the city is more valuable to us (e.g. 1000 DM per m^2) than a comparable area of land in the high mountains.

Chrzanowski

I would argue about this aspect because, in urban areas, if someone wants to buy a property he is generally not interested whether the property is for instance 400 m^2 or 420 m^2. He just likes the property and he is ready to pay the entire price not per square metre but the value of the whole property as such. Therefore, the accuracy criterion based only on the value of the land may be argued. Now, I would like to change our discussion to the question of achievable accuracy in control networks, particularly in urban areas. We would like to hear some comments from those who are involved in the surveys and then we will come to the discussion of two other questions related to the specifications for integrated survey systems.

I wonder whether Mr. Spindler could start with his comments on the achievable accuracy in the urban networks.

Spindler (Translated from German)

The real issue to be discussed here is not the achievable accuracy but, according to the formulation of the question, the achievable accuracy within certain economic limits. I have been wondering principally about the relation between economy and accuracy.

I see it in this way that the surveying specialist stands somewhere in the field between the instrument manufacturer on the one side and the survey customer on the other side. In this field I see mainly three parameters taking effect: first accuracy, then economy, and finally something concerning particularly the surveyor himself, i.e. the measuring comfort in its widest sense. To it belong such things as the expenditure with his instruments as well as the reliability of the instruments. In this field, I see the influence from the side of the costumer being relatively small, i.e. the survey user specifies little accuracy rules, and also with the costs the costumer generally exerts little influence on the surveyor. On the other side, we experience large influences from instrument manufacturers. The instrument manufacturers determine the accuracy of the instruments, and the measuring comfort as well. The surveyor then optimize particularly between these two criteria. This then finally determines the method to be employed. The accuracy itself results essentially from the measuring instrument used.

Hence, we see that the correlation between economy and measuring accuracy is actually very small. In the ranges where we normally move – other laws are, however, effective if the millimetre is to be guaranteed – mainly the tacheometric method is used. This low relationship between economy and accuracy is clearly effective here. This is confirmed also by the conditions prevailing in Switzerland. There we see that, uninfluenced by the costs or by the effective official accuracy rules ("specifications zone" 1 to 3), the accuracy simply increases. Thus, in the range of the specification zone 2 (i.e., the medium accuracy level) accuracies are achieved with the present methods and instruments being effective for instruction zone 1, i.e. for highest accuracy.

Essentially, it simply comes out that the accuracy finally has been made possible by the instrument manufacturers. Or expressed in a different way: the development of terrestrial surveying during the past 50 years practically corresponds 1:1 with the development on the instrument field, for the employed measuring methods have hardly changed during this epoch. I therefore believe that we need not talk much about economy, but we can concentrate upon accuracy itself; and here I would like to briefly present, by means of two examples, what accuracies we have achieved in the city of Zurich.

Figure III-2 shows the area of the city of Zurich with the total trigonometric (TP-) network as it was completely renewed between 1970 and 1975. The total area

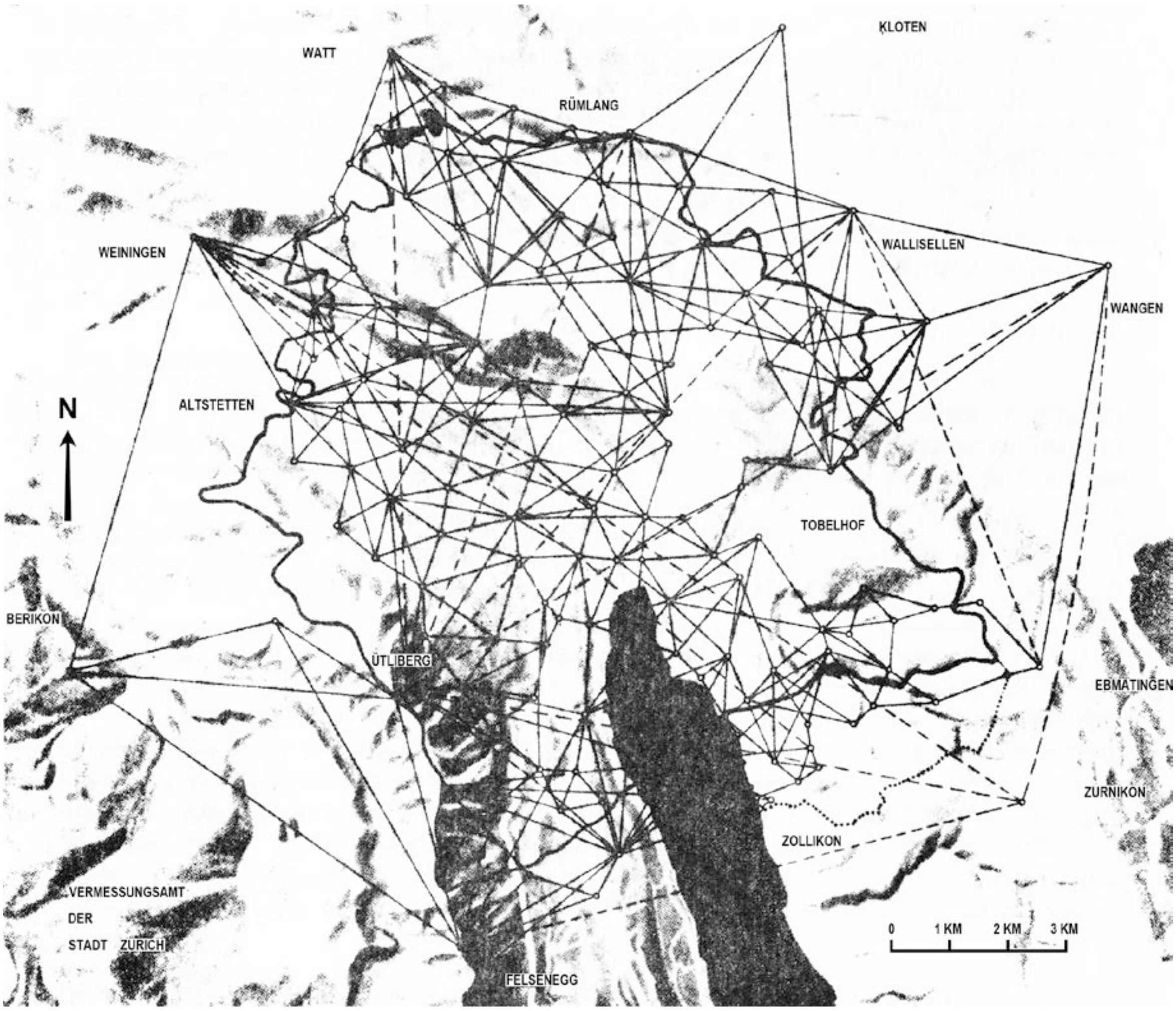


Fig. III-2. 3rd and 4th Order Triangulation (1971 – 1976) of the City of Zurich.

comprises some 100 km^2. The pertinent statistical data are shown in Table III-2.

Table III-2. Statistical Data on 3rd and 4th Order Retriangulation, City of Zurich, 1975.

Area within perimeter		*100 km^2*
Number of 3rd order connection points		*10*
Number of new 3rd and 4th order points	*(phase I)*	*164*
Number of elevated targets ♁	*(phase II)*	*62*
Number of directions		*962*
Number of distances		*438*

The accuracy that is of interest, above all, follows from Table III-3. Of particular interest is the average standard point error that could be brought down to 8 mm in this net.

Table III-3. Achieved Accuracies of 3rd and 4th Order Retriangulation, City of Zurich, 1975.

TOTAL ADJUSTMENT	
Number of orientation unknowns (u)	*216*
Degree of freedom (n-u)	*846*
Standard error of unit weight a post./a priori	*0.91*
Standard direction error	*4.1* ^{cc}
Standard distance error	*7.3 mm*
Average standard point error	*8 mm*

As an example for the consequential surveys building up on this triangulation network, I have here a diagram (Fig. III-3) for traverse surveys. In this figure each traverse is represented by a dot. Specified are the number of traverse stations as abscissa, and the linear traverse misclosure (in cm) as ordinate. As can be seen, 5 cm is sort of a magic limit.

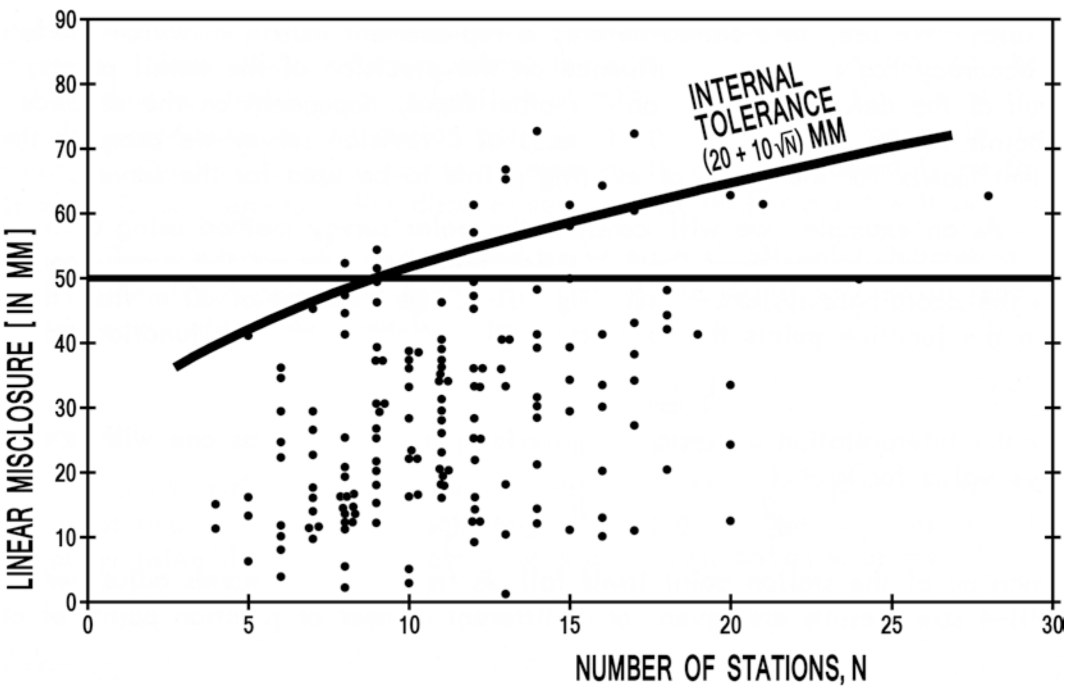


Fig. III-3. Linear misclosure (in mm) vs. Number of Station Main Traverses (City of Zurich).

These examples show the negligible relationship between economy and accuracy. The costs simply accure as the final result of the survey project without having exerted an essential influence upon the accuracy. The triangulation resulted in a price in the order of SF 5000 per point, including monumentation. Within the range of traverses there followed a point price of SF 150.

Chrzanowski

Mr. Polman, do you have any comments on the achievable accuracy?

Polman

Yesterday we heard from Professor Ackermann, and today from Mr. Spindler and other people, that the achievable accuracy of control networks can be very good. The accuracy of the detail points, especially when we want to keep them in coordinates, is a different problem. That is why I shall try to say something about that. My comment is based on my paper to be presented to the FIG Congress in Stockholm on "Testing procedures in detail measurements".

First we have to make an estimation of the precision of measurements with different instruments used for ground surveys. In our country we use the electro-optical tacheometer and the steel tape. For the tacheometer we made an estimation of 0.01 gon for the direction, that is 100 cc. The standard deviation for distances is 1.5 cm. It could be 1 cm for a lot of instruments, I think. For the steel tape we have used the formula

$$\sigma_s^2 = 5\ S_{hm}^2 + 2\ S_{hm}$$

depending on the distance measured with the steel tape.

Another estimation we had to make is the precision of an existing detail point field. We use, as I stated before, a replacement matrix in which the interpretation accuracy has a very big influence on the precision of the detail points. The precision of the detail points is, on the other hand, dependent on the distance to the other points in the neighbourhood. In case of a revision survey we compute the replacement matrix for the group of existing points to be used for the survey.

As an example, we will consider the polar survey method using a free station point. In this survey we need some junction points to connect the survey configuration to the coordinate system. Assuming an average distance of 60 m from the station point to the junction points the formula for the precision of each junction point is

$$(d_{i\ cm})^2 = 2.2 + (k_{i\ cm})^2\ .$$

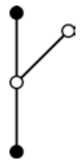
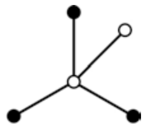
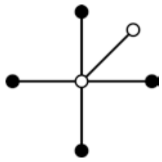
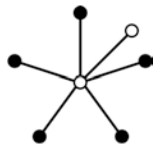
Usually the interpretation accuracy of junction points is of class one with a representative value for $k_i = 1$ cm. So,

$$d_i^2 = 3.2\ \mathrm{cm}^2 \quad \text{and} \quad d_i = 1.8\ \mathrm{cm}\ .$$

The precision of the station point itself follows from a least squares adjustment. In Table III-4 some results are given for a different number of junction points of class one.

It is interesting to see that the station point always is better than the junction points. The reason is that for the free station point the interpretation accuracy

Table III-4. Precision for Distances of 60 m.

											
precision		MX	MY	MX	MY	MX	MY	MX	MY	Junction points	
station point		1.6	1.8	1.4	1.4	1.2	1.2	1.1	1.1	MX	MY
detail points	class 1	2.7	3.1	2.3	2.7	2.1	2.5	2.0	2.4	1.8	1.8
	class 2	3.9	4.2	3.7	3.9	3.5	3.8	3.5	3.7	3.4	3.4
	class 3	7.4	7.6	7.3	7.4	7.3	7.4	7.2	7.3	7.2	7.2
	class 4	15.2	15.3	15.1	15.2	15.1	15.2	15.1	15.2	15.1	15.1

does not exist because it is not monumented.

The precision of the detail points measured from the free station point in this example is also given in Table III-4. The precision of detail points of class 1 in case of three junction points is for instance about 2.5 cm. The problem is that this is worse than the estimated precision of the junction points (1.8 cm), while these new points in the future can be used as junction points. This implies that over the course of time there will be some degeneration of the detail point field.

Another aspect, mentioned before, is the reliability of the survey constructions. To give an insight into the reliability of the free station point construction, several examples are given in Figure III-4 of the so-called limit values of the observations. These limit values represent the size of gross errors that can be detected by the statistical test with a probability of 80%. Also the influence of these errors upon the coordinates of the station point is computed. For instance, in the first configuration with four junction points an error of 12 cm can reasonably be found. If this error is not detected, the displacement of this station point will be 3 cm.

The influence of the described errors on a detail point depends on the distance to the detail point and on the position of the detail point with regard to the junction point where the error is made.

Chrzanowski

To summarize, in order to relocate a point for which we know the coordinates what accuracy would you say we are able to achieve nowaday with the present technology using the standard techniques and medium priced equipment?

Polman

The standard deviation of the computed distance between two points of class one is defined by the formula $d_i \sqrt{2}$. In our example the value of d_i = 1.8 cm,

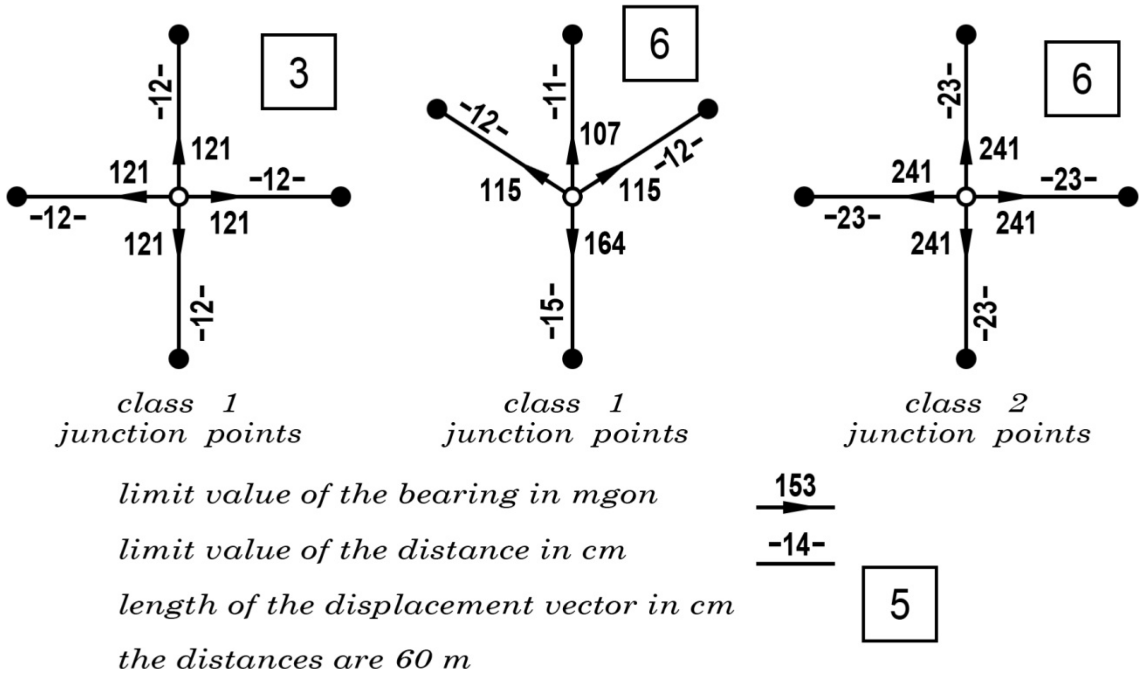


Fig. III-4. Limit values.

so the accuracy of the computed distance is 2.5 cm. When relocating a point by using a computed distance, we start from the other point with a precision of d_i = 1.8 cm. Together with the standard deviation of the measurement of the distance, for instance 1 cm, and the interpretation accuracy of the starting point of class one which is 1 cm, we come to a theoretical relocating accuracy of:

$$\sqrt{2.5^2 + 1.8^2 + 1^2 + 1^2} = \pm\, 3.5 \text{ cm}$$

as the best possible result.

Chrzanowski

Are the errors of the control points included?

Polman

Oh, yes! Of course under the condition that gross errors have not been made. But in fact the influence of the control network on the relative accuracy between two detail points is not so large.

Adler

I would like to say a few words about the control networks. Based on what we have heard in the past two days I think that particular importance should be paid to what we call lower order control. You know that the standards are specified in various survey laws by different criteria. These criteria are normally the total length of the traverse, minimum and maximum length of the traverse legs and the relative accuracy of measured distances, perhaps standard error of measured directions or of measured angles. And then also the maximum permissible misclosures in bearings and the maximum permissible linear misclosure of the whole traverse expressed as a relative error. We cannot really arrive at any uniformity in this for an international prescription. But since the importance of the traverse is growing as control for all kinds of surveys, and if we agree that the integrated surveys or multi-purpose surveys are to be carried out by various means and for various purposes, then the importance of traverses will grow more still. What I want to show you is a procedure for trying to establish a routine for choosing criteria and breaking down the network.

We have two limitations. One is the higher order of geodetic network which is normally triangulation and in my country it is something comparable to what is normally known in the literature as a third order triangulation with sides of 15 km approximately. On the other hand, for the lowest order, we can choose almost anything what we agree upon for a given country. This is the grey area of the lowest required accuracy that we were talking about this morning. So what we have done in essence is this; first of all we assume these two extremes, which for us were third order triangulation, and some kind of accuracy for the lowest order. We assumed also that the positional error m_p of a control point within a given order is composed of the error m_x in position caused by the measurements and the error m_k contributed by the positional errors of the higher order control, i.e.

$$m_p^2 = m_x^2 + m_k^2 .$$

From this we arrive at the coefficient k of step-down in accuracy:

$$k = \frac{m_x}{m_k}$$

We have:

$$m_p^2 = m_x^2 + \frac{m_x^2}{k^2} = m_x^2 \cdot \left(\frac{1 + k^2}{k^2}\right).$$

So we can write:

$$m_x = \frac{k \cdot m_p}{\sqrt{1 + k^2}} .$$

If we accept, for instance:

$$m_p = 1.1\ m_x ,$$

then we arrive at the step-down coefficient:

$$k = 2.2 .$$

Now using this we can compute the number of step-downs between a geodetic triangulation with which we do not want to tamper and the required accuracy of the weakest control points within the traverse. These are obviously in the middle and we connected them with a graphical accuracy but, of course, it does not have to be approached this way. But we have decided that this would be 1 in 4 000 while the other end was specified by triangulation and eventually arrived at a proposed table (Table III-5), where you see the 15 000 metres length of the sides of the triangulation and we got down to the 2 000 metres the total length of the survey traverse from which no control can be extended and from which only details could be surveyed. You see that these are the step-downs 1, 2, 3, and 4, between the

Table III-5. Proposed Traverse Specifications.

	TRAVERSE ORDER				
	1 st	2 nd	3 rd	4 th	survey
Length of traverse metres	15 000	10 000	5000	3000	2000
Length of single leg metres	> 3000	> 1000	400-800	150-300	80-200
Relative standard deviation distance	1:130 000	1:50 000	1:20 000	1:6 000	1:3 000
Standard deviation of angle	1".5	2"	5"	10"	20"
Angular misclosure	$3''\sqrt{n}$	$4''\sqrt{n}$	$10''\sqrt{n}$	$20''\sqrt{n}$	$45''\sqrt{n}$
Relative linear misclosure	1:50 000	1:25 000	1:10 000	1:5 000	1:2 000

Note: ① 15 km corresponds to the length of major triangulation sides in Israel.

highest order and the lowest order. Now the length of a single leg is established. The next item is that we could have to establish the required standard deviation of a measured angle (Table III-6). I do not want to go through this because it appears in all textbooks. Then you fill in the number, you complete the standard error of an angle which will vary between 1.4" for the highest order, down to 20" for the lowest order of angles. Then we compute the relationship between the angular control and the linear control which obviously have to be compatible (Table III-6). Once we have computed this we can arrive at the relative standard deviation required. And now this of course completes the whole table (III-5). And as you see this relative study of deviation of distance which appears here agrees very well with what our colleagues from Canada mentioned, 1 in 3,000 which is a realistic value. We started working with this recipe but I cannot present any reliable results because the span of time does not yet permit it. Looking at the preliminary results (Table III-7) you see that there is no appreciable difference between the sequential solution and the simultaneous solution, which is not really surprising. But what you also see is that, within the framework of each order separately the standard deviation are more or less the same. This resolution is different from relative deviations when you consider the different distances within each order. It seems, and I say this with a reservation because these results are as yet by no means conclusive, that the approach is more or less right. Whilst I do not propose to suggest that this would be a general recipe for the treatment of the problem, I feel that for any country or for any state which wants to on one hand take into consideration the existing network and on the other hand to take under consideration the local existing conditions, this may be the right approach. The higher orders of geodetic control are in existence in practically every country. With the lower order control we have to be careful. We cannot for instance, establish standards which could put a small time surveyor out of business. Therefore, for the lower order we must be careful to leave an accuracy which is achievable either by a survey tape or by an optical distance measure. And having those 2 constraints in mind the procedure is then open to establishment, and application in practice.

Table III-6. Standard Deviations of Angles and Distances.

Standard deviation of a measured angle .... m_β

$$\boxed{m_\beta = m_u \frac{\rho}{l}\sqrt{\frac{12}{n(n+1)(n+2)}}}$$

$m_u = m_t$ $\qquad$ n = the number of traverse legs

$$m_t^2 = n\ m_l^2$$

$$m_u^2 = \frac{m_\beta^2}{\rho}\ l^2\ \frac{n(n+1)(n+2)}{12}$$

$$m_p^2 = m_t^2 + m_u^2$$

Linear error $\quad m_p = \sqrt{m_u^2 + m_t^2} = \sqrt{2}\ m_u$

Relative error $\quad \frac{m_p}{[l]} = \frac{1}{T}$ $\quad$ *and for each order* $\quad m_u = \frac{l}{\sqrt{2}\,T}$

Relative linear misclosure $\quad \frac{f_{l_{max}}}{[l]}$

For higher orders $\quad \frac{1}{T} = \frac{1}{2}\frac{f_{l_{max}}}{[l]}$ $\quad$ *and for lower orders* $\quad \frac{1}{T} = \frac{1}{\underset{\uparrow\ \text{relaxation}}{2.5}}\frac{f_{l_{max}}}{[l]}$

Now introduce the above into m_β expression

	1	2	3	4	Survey
Nº of angles - n	6	11	13	21	24
St. dev. angle m_β	1".38	3".44	4".83	11".45	20"

Relative st. dev. in distance measurement

$\frac{m_l}{l} = m_\beta \cdot h$ $\quad$ *where* $\quad \boxed{h = \frac{1}{4\rho''}\sqrt{\frac{(n+2)(n^2+2n+4)}{3(n+1)}}}$

	Traverse order				
	1st	2nd	3rd	4th	Survey
Number of angels n	6	11	13	21	24
Standard deviation of angle m_β	1".38	3".44	4".83	11".45	20"
h	.00000539	.00000883	.0000102	.0000158	.0000179
$\frac{m_l}{l}$	1 : 134330	1 : 32920	1 : 20260	1 : 5530	1 : 2800

Table III-7. Comparison between Simultaneous and Sequential Solutions.

	ΔX cm.	ΔY cm.	Sequential m_R cm.	simultaneous m_R cm.
1st ORDER	0.3	0.7	1.8	1.8
2nd ORDER	0.3	0.3	1.5	1.7
3rd ORDER	0.2	0.2	1.9	2.2

$$m_R = \sqrt{m_x \ m_y}$$

Chrzanowski

Thank you very much. We are approaching already not only the question on the achievable accuracy but also how to approach the specifications for the control surveys and for the detailed surveys. We are getting a little beyond the allocated time but I would not like to cut short this discussion because I consider it as a basic discussion which should lead to the purpose of our workshop on standards and specifications. I propose that we shall take a little bit more time on this subject, cutting down a little bit of time of session V and VI. We shall try to be briefer in the last 2 sessions. Therefore, I would like to have comments on the achievable accuracy and also on the approaches and accuracy criteria which should be taken in preparations of specifications and standards for control networks and for detailed surveys.

Van Twembeke

Dr. Adler, when you speak about accuracy, do you speak about absolute or relative accuracy? And if you speak about absolute accuracy, how do you express it?

Adler

Well, obviously I cannot speak about absolute accuracy. I speak of accuracy within an order of control where the higher order of control points are for the purpose of this task assumed to be errorless and the experience seems to show that the higher order of control points contributes only about 10% of the error within the next lower order. So accuracy is relative to the framework of the higher order of control, and is not an absolute accuracy.

Van Twembeke

Yes, in our problem of large scale maps we are exclusively interested in the relative accuracy within a given area.

Adler

Yes, I agree and I fully agree with what Mr. Polman says in his paper. I think what is most important is the accuracy within a certain radius from the point of concern and so I fully agree that what is most important is a relative accuracy within a given area. It is almost immaterial in cadastral surveys, in my opinion, whether the detailed points, or the boundaries are very accurate with the relation to the first order geodetic framework.

Neisecke (Translated from German)

I have a question for Mr. Spindler concerning the accuracy of the values in the neighboring region beyond his network, i.e. outside of Zürich. How does it look like there? Have you checked that? For, a jump in the coordinates may now occur, i.e. if you introduce the coordinates of the trigonometric points of Zürich. What difficulties have been encountered, and how can this be treated on further? Or, how do you see that?

Spindler (Translated from German)

There naturally exists an influence. I believe this is a principal problem which I would have brought up in the next point.

Previously, there was the one-way idea of working from the hierarchically higher order to the lower order. Now it is such that we are able to remove a partial domain from this hierarchy. This results in problems because we have again to consider superior hierarchies. Lower hierarchies may in all events be measured more precisely with newer methods than the higher hierarchy according to the old method. This problem has turned up here. We have seen that the 3rd order points which we would have to join to, had accuracies in the order of 5-10 cm, whereas we come within the range of one centimetre in the new network (3rd and 4th order). We solved the problem by elastically constraining the new, very accurate and homogenious net; we changed the original connection coordinates on the grounds of individual clarifications and in cooperation with the authorities responsible for these points. With us, this is for the 3rd order the Eidgenössische Landestopographie. They then allowed us to change the original connection coordinates on the grounds of our better measurements and a complete adjustment. It is now the Kanton Zürich's task to investigate how far out should these changes, that maximally reached some 3 cm, be processed.

Ebner

I have a comment on the statement of Mr. Spindler who told us that the measuring procedure itself determines the accuracy and the economy of the system, and that it is almost impossible to reduce accuracy for the purpose of improving economy. This is certainly true for surveying, but not for photogrammetry, where both accuracy and economy are functions of the photo scale. I.e. that by using photogrammetry, you can obtain exactly that economy or that accuracy you need.

Spindler (Translated from German)

I agree absolutely with you. I have to point out the fact that this session III deals only with the methods of ground surveying. If we wanted to discuss the, certainly existing, relations between terrestrial and aerial photogrammetry methods, this would be beyond the scope of this session (see session V, edit.). Here, I just would like to say that for city surveys the central point is revision. The primary survey is done, and we only move in small areas to detect and deal with changes. Photogrammetry will here, even on a long-term basis, not get a chance.

Chrzanowski

Let us start now with the question: how should the technological progress affect the development of new standards and specifications? I noticed for instance that in several European cities, the standards and specifications are really out of date. They are still based on the achievable accuracy using, for instance, steel tapes.

The standards and specifications were not created on the basis of the real needs of the users but on the basis of whatever precision could be achieved using available technology. Now is the time to review the approach to the standards and specifications, particularly with the use of electronic instruments for measurements and the use of computers for calculations and statistical error analysis. Probably, a completely new approach to standards and specifications should be taken due to the rapidly changing technology. Maybe we don't need any more to specify such details as, for instance, that in order to achieve the accuracy of the control network such and such angles should be measured in so many sets using a 20" theodolite, the number of traverse legs between junction points should not be larger, for example, than 5 and the ratio of the shortest leg to the longest of the traverse shouldn't be larger than one to three and so on. With the use of even small computers, every surveyor with a proper educational background should be able to make a proper accuracy pre-analysis based on the simple error propagation in order to arrive at what type of instrument and what survey methodology should be used in a particular project in order to achieve the required accuracy. The specifications could be given in a more general way. They could say, for instance, that positioning of corners of the property boundaries in respect to the control points should be established with the semi-major axis of the relative error ellipse of 2 cm at the 95% probability level, and it should be up to the surveyor to select the proper instruments and proper survey techniques as long as he could prove on the basis of the error propagation that he could achieve the specified accuracy. It should be enough for the examination office to check his proof that he obtained this accuracy, instead of specifying exactly all the survey procedures, instrumentation and so on. Of course, it is one idea and one possibility of approaching the standards and specifications. It may be that many practising surveyors would object to that idea. Probably we could give an option to the practising surveyors by giving him the detailed specifications plus the option that he does not need to follow the specified field procedures as long as he can prove on the basis of a rigorous error analysis that he is able to achieve this accuracy using different survey procedures. So here is the problem of the approach of the specifications.

Adler

I just want to strongly object to what Dr. Chrzanowski said about individual preanalysis. I feel that when you get down to the practising surveyor you cannot leave the freedom to the surveying community to use whatever methods they feel are applicable subject to proving that they are right; you would have endless disputes between the checking office and the private surveyor. I really feel that the specifications must be made. Of course they must take into consideration the technological advances. But we still have to say, and I feel that this goes for any country, starting from the most advanced ones in Western Europe down to the emerging countries in the heart of Africa or Asia, that you have to specify how many rounds have to be made with the theodolite and how many distance measurements have to be taken in order to achieve a certain accuracy. I don't see any possible deviation from this. This is one comment. The other comment is that the whole question is paradoxical in a way. We are asking ourselves what is achievable through the newest instruments, through the technological advances and improved methods but the basic question remains "What kind of an accuracy is really required in the end?" This should be the starting point, not the technological advances.

Chrzanowski

This was the reason why we have started our discussion with the topic: "What accuracy is needed?" We knew in advance that we could not give the answer today. We still don't know whether we should try to use all the advances of technology in order to improve the accuracy. Maybe it is not needed.

McLaughlin

I just want to make a comment regarding Dr. Adler's statement, I guess, a strong objection to his statement. In the North American context the professional surveyor (and here we are thinking of the new surveying professional coming in who is well educated, capable of knowing preanalysis, post-analysis, very capable of dealing with quality information parameters), this person is not going to be tied down with rigid specifications. He is going to want to use the freedom to explore new techniques, new problems, new technology and new instrumentation. His results will certainly be publically examined. They will certainly have to meet quality parameters. But I am quite sure that the profession is not prepared to have what used to be called a handbook approach in civil engineering. In North America I do not think the surveying profession will accept this philosophy.

Adler

I think that Dr. McLaughlin is speaking from an experience with a very unusual group of people. This is certainly not the situation in most countries. The practising surveyor has very little to do with the academic analysis of accuracies and methods.

Kuranchie

Mr. Chairman, this is a contribution in support of Dr. Adler's statement.

The situation in developing countries is certainly different. The type of professio-al calibre Dr. McLaughlin is talking about in the North American context does not exist in our part of the world at present. This means it will definitely take a long time before we do away with official guidelines in the execution of cadastral surveys. These guidelines, in my opinion, are only the minimum to ensure that standards are maintained. Asking that distances of survey lines are to be measured with a well standardized tape from two directions, and that angles are to be measured in two phases within a reasonable accuracy, I think is not asking too much. Yet, these are simple guidelines, if adhered to will make it possible for checks to be instituted easily on works submitted.

Until the time that we have trained and independent professional surveyors in the mist of the licensed surveyors, I will certainly not advocate a sort of open license to the licensed surveyors to use whatever means is at their disposal to execute a cadastral survey. Some types of layed-down specifications and guidelines drawn by National Survey departments in consultation with the professional body concerned are still necessary, for after all the National Survey Departments are the arbitrators between the professional surveyors and their clients. Their sole aim, I believe, is to ensure that standards in survey works are maintained. Thank you.

Chrzanowski

I agree, as a compromise between the two extreme approaches, that even quite detailed guidelines or suggested procedures should be given to the surveyors. However, at the same time, we should leave an option to the surveyor, that if in special circumstances he has to use different instruments or longer traverses than allowed by the specifications he should be allowed to go ahead as long as he can prove theoretically and on the basis of the knowledge of the accuracy of the instruments, and using the new computing technology, that he is able to achieve the required accuracy even if his procedures deviate from the suggested procedures. Later on the examination office should have facilities to check, whether the specified accuracy was achieved or not. The option should be given other than just the rigid specifications which may become out of date in another 5 or 10 years. We have now the problem that our specifications are 30 or 40 years old and still we are using them even though we are using a completely different equipment. So I would be in favor of a compromise in the specifications: rigid guidelines plus a option for the surveyor that, if he is able to prove that he is obtaining the required accuracy, he can then deviate from the suggested procedures.

Kuranchie

There used to be what we termed a "portable error", inclined to access the plan which is normally prepared by a land surveyor. When discussing coordinates, i.e. the numerical cadastre, does it mean that we are going to do away with this error measure? The whole thing is related to scale. Again, would this mean that we are going to do away with accuracy related to the scale of the presentation of the actual map sheet?

Chrzanowski

It is now a question whether we are going to the graphical system or into the numerical one or into the combination of graphical and numerical system. So again it is a question that different specifications will be needed for the graphical systems and for the purely numerical systems. I can see that some problems are emerging now from our discussion and we are not able to solve these problems over here, but at least it will give some guidance for the study group which eventually will be created.

Waldhäusl

I agree very much with your opinion that we steadily have to review our way of thinking. The cadastre of the future will certainly be a numerical one with automatic graphical output from the data bank. The graphical information is needed, for nobody is able to think or plan with only point numbers and coordinates.

The graphical updating of the old cadastre has meant accumulative loss of accuracy. Therefore, numerical revision and multi-level data banks seem to be promising. The multi-level data bank enables us to preserve all surveys (not only the cadastral surveys, and that is important for town surveys especially) of any area. The accuracy of the survey results depends on the purpose of the surveys, for the purpose dictates time and funds available for the surveys. As there are surveys of different accuracy level within an area, we should enforce by law the funds available for the surveys. As there are surveys of different accuracy levels within an area, we should enforce by law more information about a point's coordinates: We should add some information about the accuracy (how exactly measured?), about the reliability (how often measured independently?), about the monumentation and the point's definition (is it a fine brass-bolt in concrete or some raw rock?) and finally we should consider some sort of dynamic classification of the monument (Is it stable or may it be moved? Is it moving? Endangered?).

Only then shall we have established a coordinate data bank which can be relied upon safely and which can be used together with the other levels of information.

Chrzanowski

Well, we have no time, right now to prolong this discussion. Probably we should touch upon some of those problems in session V and particularly in VI where we should try to outline the problems which need some further investigation. Thank you very much. We shall now start session IV with brief presentations concerning the results of some pilot projects.

SESSION IV

REPORTS ON PILOT PROJECTS ON INTEGRATED SURVEY SYSTEMS

Moderators	A. Chrzanowski (Canada) E. Dorrer (Germany)
Reporters	– J. McLaughlin (Canada): The Maritime Land Registration and Information Service (L.R.I.S.) – H. R. Andris (Switzerland): A Graphical-Numerical Interactive System (GNIS) – E. Stark (Germany): The Project Appenweier – L. Mauelshagen (Germany): Rheidt Test Field Analysis – K. Blachnitzky (Germany): Moosach Project – P. Waldhäusl (Austria): The Vienna Experiment of OEEPE/C.

SESSION IV

Chrzanowski

We shall now start with session IV in which summaries of some pilot projects will be presented. We would like to ask the reporting persons to concentrate on the approach and on the results only, without details of the pilot projects. Otherwise we would not have time left for sessions V and VI. We would like to learn whether there is any overlapping between projects in different countries. This would be an important point for the eventual study group of F.I.G.

Dorrer

I would suggest that we perhaps make a start of transition period between the ground survey approach of session III just finished, and between session V with the more photogrammetric approach. Accordingly, we should start with the pilot projects belonging to the ground surveying side; i.e. first John McLaughlin, second Mr. Andris, and we would then switch to photogrammetric projects in the sequence: Stark, Mauelshagen, Blachnitzky and Waldhäusl. We would then be ready to discuss in session V the question "ground vs. photogrammetric surveys".

THE MARITIME LAND REGISTRATION AND INFORMATION SERVICE (LRIS)

The Canadian Maritimes consists of the three small Atlantic coastal provinces of New Brunswick, Nova Scotia, and Prince Edward Island, having a total area of 52 000 sq. miles and a population of approximately 1 500 000. The present land tenure arrangements are the product of a combination of French and British settlement efforts. The initial colonization was attempted by the French in the seventeenth century. They made approximately 30 large, seigniorial grants covering most of what is now New Brunswick. In only a few cases, however, were serious efforts made to bring settlers to the region. During this period, a small number of surveys were carried out by French engineers and a few Royal patents were issued. Following the fall of Quebec in 1759, large tracts of land were granted by the English Crown in the Maritime region, specifically for settlement purposes. In the beginning, this land was often granted collectively to groups of settlers in the form of townships. These grants frequently included one hundred thousand acres and more, and were usually situated either along the Atlantic Coast or along strategic rivers and streams. Within each township, and shares would be allocated to individuals by proprietors' committees.

This township system survived for only a short period as the principal means of granting land in the Maritimes. Settlers began to simply locate themselves in desirable areas outside the recognized townships, and later other grants would be made contiguous to them. During the nineteenth century, extensive, irregularly shaped grants of timber lands were conveyed in New Brunswick and Nova Scotia, thus furthering an unsystematic pattern of land holdings. While the original land grants were made by the Crown, the subsequent transfer of grants was entrusted to a rudimentary deeds registry process under which the individual grantee was responsible for registering his grant in a county deed registry office. The registration, while not mandatory, served notice to the public that the purchaser claimed a merchantable title to the lot.

In the Maritimes, distinction was always made between cadastral surveys conducted on behalf of the Crown and those made for private individuals. The initial surveys for alienating land from the Crown, and the subsequent retracement surveys for the maintenance of the Crown boundaries, were, from the outset, the responsibility of the respective provincial governments. The Office of the Surveyor-General was one of the first public offices established in each province, and legislation was enacted providing for the commissioning of deputy land surveyors to act as agents of the Surveyor-General. However, while formal processes evolved for the execution and examination of Crown surveys, similar processes were not developed for privately executed surveys. Until the mid-1950's, there was no control over surveys carried out for private parties, except for certain requirements for the registration of professional land surveyors. Standards of practice were not officially adopted and formal registration of boundaries was not required. Both public and private surveys were of an unsystematic nature and deed descriptions were based upon metes and bounds.

Perhaps the first step in the long and arduous process to change the arrangements described previously came in 1944 with the presentation of a brief to the New Brunswick Committee on Post-War Reconstruction. In this brief, the New Brunswick Forest Products Association stated:

There is a need for the organized and supervised survey of property boundaries with adequate monuments so that boundaries can be renewed without disput ... There is a need for up-to--date accurate property maps for municipal taxation purposes. Control surveys are necessary as a framework for making line maps, and the survey of municipal and property boundaries can be combined with control surveys and used for this purpose. An arrangement should be worked out between the Province, the municipalities, and the property owners to have this work done.

While this need for a densified control system was recognized by surveyors and foresters in the 1940's, the actual establishment of such a system was to prove prohibitively expensive until the mid-1950's, when the development of electromagnetic distance measuring instrumentation made it economically feasible. In 1958, which may be considered the genesis of the Maritime Land Registration and Information Service, the New Brunswick Coordinate Survey Program was formally organized within the provincial Department of Lands and Mines. The system was designed as a second-order plane coordinate framework based upon a secant stereographic projection. Horizontal control was established by second-order traversing between first-order triangulation stations, previously established by the Geodetic Survey of Canada. Vertical control was established by third-order spirit leveling and supplemented by trigonometric leveling. In 1967, a provincial Surveys Act was passed which legally defined the coordinate system, provided for its continued maintenance, and introduced the concept of the integrated area. The act further provided that the Lieutenant-Governor in Council could designate any portion of the province as an integrated survey area, within which it would be required to tie to the coordinate system, all surveys that:

(1) Pertained to Crown lands;

(2) involved subdivision which required a subdivision plan under the Community Planning Act; and

(3) involved parcels of land which the owners request to be included.

By the mid-1960's, large portions of the province had been monumented and surveyed, and the results had been adjusted. At this time, the provincial government initiated a modern, large-scale mapping program. This program was designed to provide 1:10 000 and 1:20 000 orthophoto maps throughout the province, and 1:1 200, 1:2 400, and 1:4 800 linedrawn maps in selected areas. All map sheets were to be produced in both planimetric and topographic editions. In 1968, as part of a regional economic expansion program, the Federal government agreed to participate in the funding of both the control densification and large-scale mapping programs, and extended the program to the two other Maritime provinces. The basis for the Federal support was the belief that secure cadastral infrastructure arrangements were necessary for any efforts to enhance economic development in the region.

During this same period there was a growing belief that the large-scale surveying base and the accompanying administrative structure, in the process of being established throughout the region, could beneficially serve as the foundation for a modern multipurpose cadastre. It was envisaged that this could be accomplished in a four-phase endeavor:

1. Phase I – the extension and densification of the second-order control survey system as quickly as possible.

2. Phase II – the development of the large-scale planimetric and topographic mapping program throughout the Maritime provinces, and the introduction of a large-scale property mapping series.
3. Phase III – the sequential replacement of the rudimentary deed registry system in each province with a computer based land titles system.
4. Phase IV – the gradual development of multipurpose cadastral records.

Professor Hans Larsen, of the University of New Brunswick Department of Economics, was commissioned by the Canadian Federal government in 1971 to prepare an economic feasibility analysis of this program. He concluded that:

> *The overall study findings indicate a strong and growing demand for all service categories. There is absolutely no doubt that the services in question are essential to a wide variety of activities – no organized society can function without access to standardized, timely information services of adequate quality. It is equally clear that the old "system" will not longer suffice – modern technology and procedure require co-ordinate control, and the maintenance and development of the Region's resources, environments, and facilities – the traditional land registry system never did provide fully adequate services in the first place; it always constituted a highly, unsophisticated, incomplete collection, too often riffled with errors and omissions.*

Acting on Larsen's findings, the Federal government and three provincial governments established the Maritime Land Registration and Information Service in 1972 to develop and implement a multipurpose cadastre based on the four-phase approach. Initially, it was envisaged that the multipurpose cadastre would be established in the Maritimes over a period of at least 50 years. Significantly, pressures from the users of land information have forced a 10-years completion schedule.

Much of the first and second phases of the LRIS program are now complete, and attention has been shifted to maintenance surveying. One current area of concern is the simultaneous adjustment of a large number of heterogeneous surveys (which are the result of the evolutionary nature of the survey and computational facilities), coupled with the redefinition of the North American datum.

The third phase of the program is focusing on the improvement of the Maritime deeds registry systems and the gradual conversion of these passive systems to active, torrens-type land registration. Much of the effort to date in this phase has been directed at property mapping, implementing integrated survey areas and preparing draft legislation. An inordinate, and probably unfortunate amount of time and money has been devoted to the design of computer software. At the present time, a debate is raging over whether boundaries should be guaranteed in the proposed active registration system. There are various technical, legal and economic issues yet to be resolved.

Work on the fourth phase of the program is still at an early research stage of development, with considerable conceptual concerns yet to be straightened out.

As I have mentioned, much of the attention to date in the LRIS program has been devoted to technical surveying and computerization issues. In the future, much greater attention will be given to socio-economic issues. Justifying the need for modern surveying and land information systems, coping with the social costs entailed in technology transfer, acquiring the necessary human and material resources in a depressed economy – these will be the primary concerns of future managers.

For a more detailed examination of North American cadastral systems see McLaughlin, John and James Clapp; "Toward the Development of Multipurpose Cadastres"; Journal of the Surveying and Mapping Division, ASCE, September 1977.

Andris

A GRAPHICAL-NUMERICAL INTERACTIVE SYSTEM (GNIS)?
(partly translated from German)

There are three important information domains: persons, finances, and land data. Surveys furnish the basic information, maps and registers for planning land data. Not all map information is graphic. One important function of maps (surveys) is to link nongraphic data (legal information, statistics, descriptions and other text and numbers) with specific geographic locations. We think that this belongs to an integrated survey system, and therefore only a graphical-numerical interactive system can meet the requirements. With a GNIS we can build up and maintain a land data bank. From that we can:

a) produce maps
   – any scale (within a certain range)
   – whatever format (plotter limited)
   – desired contents
   – any time
b) do calculations
c) control the data base virtually and numerically, print registers.

A very important consideration for integrated survey systems is that we now have an adequate instrument in the office in addition to the automatic field registration. The potential of the automatic chain can be fully utilized. The reason is that we do not need to give numbers to the points because we can work directly with coordinates and certain identification codes.

We have been looking for a GNIS for years. Now we have found one, the calmagraphic interactive Data Management System. CALMA Company (U.S.A.), CALMA GmbH (D) is an internationally established supplier of data reduction and interactive graphic systems with more than ten years of experience.

The product lines are:

CG Calmagraphic (Data Reduction System for photogrammetry)
CGI Calmagraphic Interactive (Land Data Bank Management System)
DDM Drafting Design and Manufacturing System (3-dimensional Geometry Construction)
GDS Graphic Data System (for Integrated and Hybrid Circuit Mask Layouts).

The CALMA-CGI has the following system objectives:

– throughput
– flexibility
– correlating nongraphic data to graphics
– simplify data entry and editing
– high quality and fast plots
– communication with other computers.

The calmagraphic interactive system is based on the DATA GENERAL ECLIPSE S230 minicomputer with at least 48 K words of core with up to 8 disks (80 to 300 M Byte). A magnetic tape unit and a Decwriter II are standard system components. Large mass data storage is provided for three reasons:

– floating point arithmetic is used to provide the precision. The data base provides 48 bits, i.e. more than 9 digits of precision;
– cartographic data bases consist of very large data files;
– effective map data management needs more detailed file structuring than pure graphic tasks.

Up to 5 digitizing or editing stations may be connected. All stations may be used simultaneously for data capture, interactive editing and updating, data management, and selective data retrieval. Three plotters can be driven.

The <u>calmagraphic interactive data base structure</u> consists of four classes:

- drawing
- overlay (0 + 1 to 32)
- domain (29 levels unlimited subdomain)
- group (65000 for each domain).

Figure IV-1 shows the drawing name MAP with five out of 32 possible overlays. Attached to overlay 3 (3 OV) are here three level-1-domains (TOPOGRAPHY, etc.) as well as group 1 (1 G) containing the map border. Attached to the IMPROVEMENTS domain are three level-2-domains (PRIVATE, PUBLIC, etc.). Attached to the PUBLIC domain are four level-3-domains (STREETS, etc.), where four level-4-domains (FEDERAL, etc.) are attached to the BUILDINGS domain. Finally four groups are attached to domain FEDERAL.

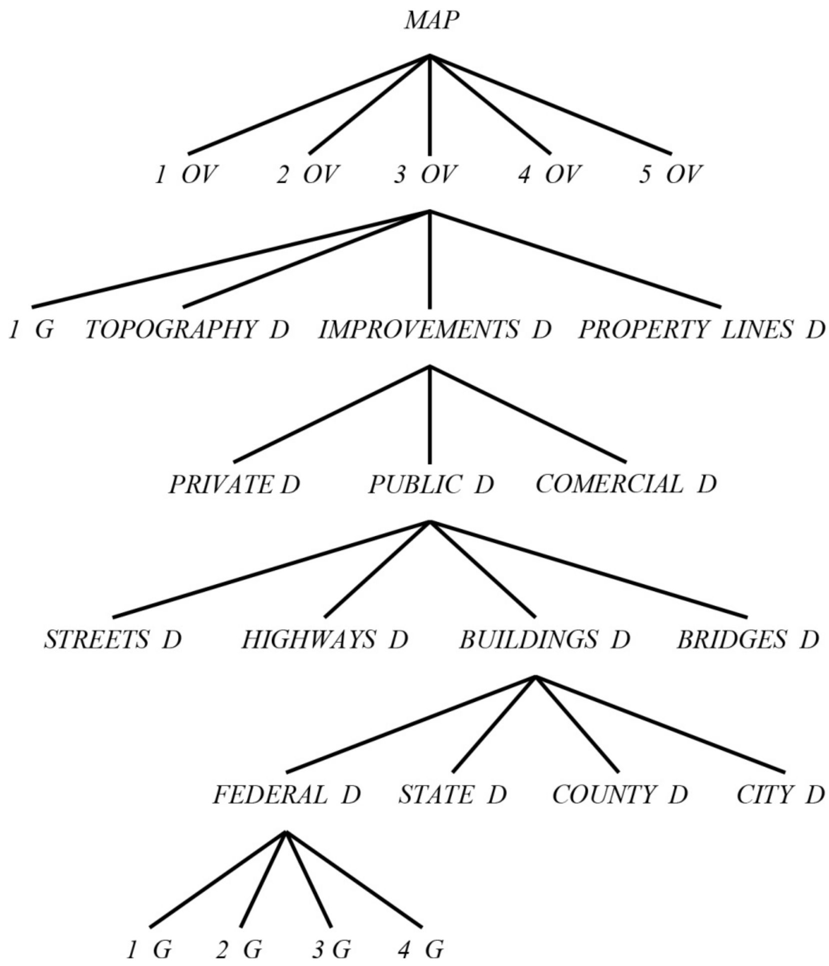


Figure IV-1. Calmagraphic Interactive Data Base Structure.

In addition to the usual point and line data the CGI can define symbols. Complete symbol libraries may be stored. It is also possible to associate nongraphic data with graphic data. The nongraphic data is stored in information blocks (IB). Each IB may contain an alphanumeric text string, a numeric value or a reference to a library file.

With the command programming language (CPL) the user can set up sequences of CGI commands called functions (macros). CPL functions can test the success or failure of previous commands and, depending on the result, execute alternate commands. The operator can interactively change, move, copy, delete or add graphic and text data, aided by the menu and functions keys.

The calmagraphic interactive system is an integrated, turnkey, hardware/software graphic data manipulation tool.

We installed the CGI system in August, 1976. The system is used for renewal of the cadastre, for base surveys and for updating. With it, we can save old maps by a combination of field measurements and digitizing. We should then with time be able to exchange the "graphic" coordinates with "measured" coordinates during the updating process.

Within one month after its installation, the system was capable of properly processing and producing different types of maps at different scales. The man assigned to this task had no previous knowledge of data processing; despite his poor English he only needed to attend a 5-day introduction course.

In the following section, the mode of operation will be discussed, the importance of graphical-numerical interactive computer systems emphasized, and its implications upon surveying in general will be presented.

Since surveying has been practised, the techniques of a graphical-numerical interactive system have always been used. The survey specialist works graphically (map production, geometric constructions by compass and ruler, etc.), numerically (calculation of lengths, coordinates, areas, etc.) and interactively (tasks are performed, results examined, and the tasks, e.g. computations, revised). The only new thing about GNIS is that for the first time all surveying activities can be handled with a computer assistance. The system components of a GNIS will be explained exemplarily for the CALMA system of the survey office of the Kanton Aargau (Fig. IV-2).

The heart or control center of a GNIS is a minicomputer. The survey data and the programs are stored on one or more magnetic tape units. The tape unit serves for the data transfer to another computer system through tape, or for securing of information stored on disk. Attached to the system are operating stations for different tasks. A first type is the digitizer station consisting of a digitizer table and a graphic display terminal. This station serves for an exact acquisition of coordinates from a copy (map, etc.). Here, the display terminal serves as a guidance to the operator, and mainly for a direct control of the performed operating steps. Another type of operating station is the computing or editing station. At it the operations are carried out directly on the screen with the aid of a light pen or a cursor. Starting points are labelled, field survey data are keyed in, and the results are displayed graphically and numerically. Texts and numbers are further inserted and positioned into the stored graphics. Besides the display terminals automatic plotters and printer/writers serve as output media of a GNIS.

What are the operations while surveying with a GNIS? First the mode of

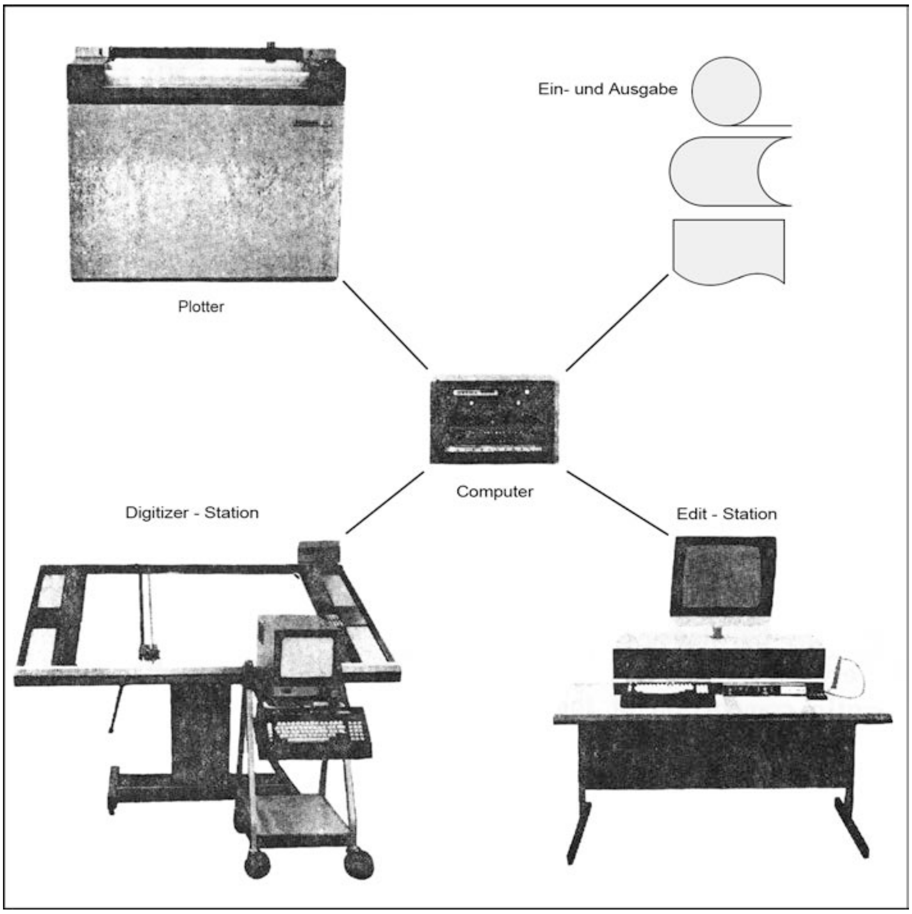


Figure IV-2. The CALMA System installed at the Survey Office of Kanton Aargau, Switzerland.

operation in connection with a base survey, then with a renewal of the cadastre will be explained.

Base Survey ("Neuvermessung"):

(1) Field measurements and surveys are recorded.
(2) The point coordinates are computed in batch-mode, not interactively; they are meaned and checked by means of customary EDP-programs, at which stage not all errors may be cleared up.
(3) Within the GNIS these data can now be put into memory and made visible.
(4) The remaining clearing-up is performed interactively. Intersection points will be defined and computed.
(5) The parcels of land can now be defined directly on the display by using the survey sketch. The boundary points are specified approximately by means of a light pen. On the magnetic disk the exact coordinates of the points are determined, the definition class examined, the connecting lines (straight lines or circles) are defined and checked for parity with the neighboring lots, and the result is shown on the display screen. When the lot is closed, its area is computed and put into memory. Now, the lot numbers must be positioned, viz. the one for map scales up to 1:1000, the others for smaller scales.
(6) Still missing situation points, e.g. a fourth house corner, etc. will be "constructed" on the display screen in the same way as on the map by being computed by

means of arcs, intersection of straight lines, right angle traverse, etc.

(7) Subsequently, the buildings (including lettering) with extensions can be defined, i.e. the computed points made visible on the display will be connected with each other like on a map. Additional constructions such as walls, street edges, are produced.

(8) The cultivation boundaries must still be defined, and statistical calculations concerning acreages must be performed.

(9) Checkplots will be produced, and corrections made.

(10) Then the automatic final drawing is done with ink, or scribed on film, or by means of light at the desired scales and with the demanded contents.

(11) Finally the records will be provided.

Renewal of the cadastre by digitization:

(1) Clearing-up the maps and the list of traverse points.

(2) Putting the traverse and triangulation points into memory of the GNIS system.

(3) Digitization of the entire map contents (boundaries, buildings, cultivation boundaries, etc.) including connecting lines, all in map coordinates.

(4) Transformation of every individual map into the coordinate network of the traverse points by means of the traverse and triangulation points.

(5) For every map interpolation of the residual transformation errors.

(6) Automatic comparison of the map edges, and meaning of the edge points.

(7) Clearing-up of edge errors, e.g. by computing the points from field survey data.

(8) Partial check of the digitized boundary points by distance measurements ("Spannmasse").

(9) Performance of possible correction mutations.

(10) In cases where the projection system has to be altered within this cadastre renewal, similarly to steps 1 to 9, some 6 to 8 points are to be determined by field measurements by means of a new, precise and wide-meshed traverse network spread over the area.

(11) Transformation and interpolation into the new projection system.

(12) Checkplots in different scales.

(13) Establishing the new records.

Appearing obvious from the description of the operations for base surveys and cadastre renewals is the necessity of qualified personnel generally. GNIS is but one, however "intelligent", tool. Still, both the engineer and survey technician are primarily responsible for the proper assessment of the survey results (field and office). For the graphical organization of information the skill and the eye of the survey draughtsman is required. Frequently there is the fear that the place of work looses substance when EDP is introduced. This is not the case with a GNIS, for this system functions completely transparently for the specialist. With the aid of a "menu card" separated for every working field (Fig. IV-3) the human operator can select and activate his own operating steps. The computer language need not be known. By pointing to the menu field with a pen, the function associated to this field will be released, and the operator will be guided by instructions displayed on the screen.

That is all very fine, but why does the survey profession need graphical-numerical interactive systems?

(1) Up to now the field measurements have been done in the scale 1:1 and, with high expenditure, were unnecessarily changed for the worse by the plotting process. GNIS enables the survey to be done in the scale 1:100 ..X (X for survey accuracy).

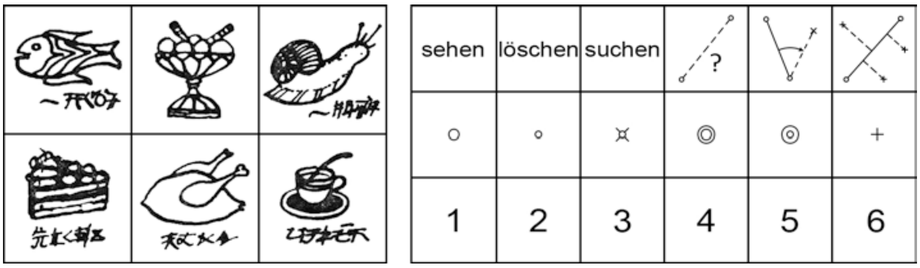


Figure IV-3. Selecting and Ordering (Activating) a meal and (an Operation Step) does not Require Knowledge of the Computer Language.

(2) The employed EDP methods so far, whether with large, small or mini computers, have made map and coordinate revision possible only for a part of the survey enterprise, viz. the boundary point coordinates and the definations of the parcels of land. Even in rural areas this information constitutes only 20 to 25% of all current survey data. By introducing the multi-purpose cadastre, the information content to be administered will at least be doubled. The use of GNIS will therefore become indispensable.
(3) GNIS enables a fast and cost-optimal renewal of the cadastre. In the Kanton Aargau one third of its area, i.e. 460 km^2 is mapped on sheets; the question is to save these.
(4) The survey volume of the so-called surveying program 2000 amounts to roughly one billion Swiss francs. A fast and cost-optimal realization requires the use of most modern means such as GNIS.
(5) The use of self-recording theodolites in the sixties failed with the numbers of points. GNIS needs point numbers on a very limited basis only. Connecting link between computer and man is the graphics' coordinate.
(6) GNIS allows simultaneous revision for the various map scales.
(7) GNIS enables the maps to be generated in any format, scale and content. There is no need any more to keep map series in stock, which then cannot be revised due to costs and time.
(8) GNIS is a data collection and data manipulation system. The survey is not fixed to a product as is being done until now. Products such as tables, maps, records, etc. may be specified according to the requirements, they may be generated and offered quickly for the purposes of a good service.

We can finally say that, by employing GNIS, no places of work are endangered; quite the contrary, by improving the service and the product innovations, new ones can be created. The purely manual drawing of lines, etc. loses its significance within the realm of survey draughting education. The training for the graphical organization of maps, however, must be intensified. The installations of graphical-numerical interactive systems in Aarau and in Basel have demonstrated that the GNIS's are not laboratory systems any more, rather they are production systems.

With GNIS we are now in a position to meet the demands of the customers also as far as the graphical organization is concerned. Up to now the problem has always been that a map with certain content exists; however, if a different map content was needed, long waiting times had to be taken into account. This is much too late for the customer because, as experience has shown over and over again, the requests to the surveyor usually arrive always at a time when they should have been already satisfied. With the existing graphical-numerical interactive system we now believe we are able to simply make a jump ahead; no longer be one who must produce something quickly in the end, but rather be in a position to give a real service to the customer.

Stark

THE PROJECT APPENWEIER

Up to now several tests have been performed to investigate the capabilities of photogrammetric methods for the densification of existing trigonometric networks. One of these tests is the project "Appenweier" which has been initiated by the state survey authorities of Baden-Württemberg, West-Germany, and which has been performed with the cooperation of the Photogrammetric Institute of the University of Stuttgart. The test area Appenweier is located in the Rhine valley, covering approximately 9 x 10 km^2. In it, 24 trigonometric points were given as control points, and 85 points gad to be determined. These 85 points could be used as check points for the test since their coordinates were known. The accuracy of the terrestrial coordinates was supposed to be about 1 cm.

The aim of the project was to achieve a planimetric accuracy of about 3 cm in the terrain, which demands a photo-scale between 1:3 000 and 1:5 000, assuming image coordinate errors of 6 to 10 µm. However, due to expected difficulties with the point transfer in very large scales it was decided to use a photo-scale of approx. 1:8 000 with 4-fold overlap. The 4-fold flying was done in 4 different flight directions from east-west, west-east, north-south and south-north. Figure IV-4 shows a sketch of the test field with its control points and with the 4 flight directions. The chosen flight configuration was expected to improve the accuracy of the block-adjustment by even more than the factor 2, compared with single coverage at the same scale, due to the expected reduction of systematic errors. The total number of models was 448 (7 strips with 16 models each in east-west direction and 8 strips with 14 models each in north-south direction).

All points were targeted by 20 cm by 20 cm signals. The control points had attached 4 auxiliary points, forming a cross, and the check points had 2 auxiliary points, forming a straight line with fixed distance. In addition, according to the special test purpose of the project, all tie points (6 per model) were signalized with triple signals, forming a triangle.

Aerial photography was taken in two missions in April/May 1973. Because of bad weather conditions the signalization had to be maintained for about 2 months. A Zeiss RMK A 15/23 wide-angle camera was used. The film diapositives were measured with a Zeiss stereocomparator PSK2, and relative orientation was performed analytically. For block adjustment the independent model program PAT-M-43 was used. After block adjustment least-squares interpolation was applied in order to reduce systematic errors as far as possible. Besides the aim to test the applicability of photogrammetric methods for network densification, the test material could serve some other purposes:

1. Investigation of height accuracy;
2. Investigation of point transfer methods, i.e. comparison of natural, artificial and ideally targeted tie points.

<u>Results of horizontal block adjustment</u>

The block adjustment were performed with 2 different control point versions:

1. With all given control points (perimeter + points inside the block).
2. With dense perimeter control only.

In addition, different overlaps were investigated, i.e. single blocks, double blocks

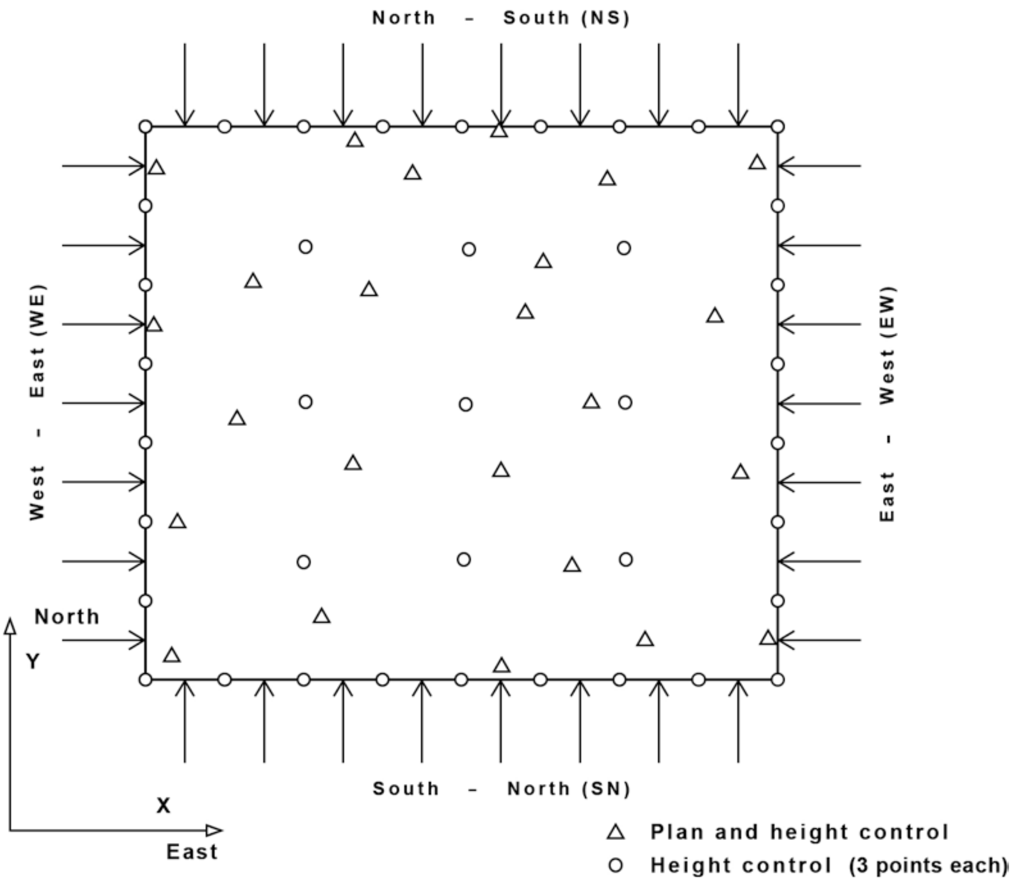


Figure IV-4. Appenweier, Flight Plan and Distribution of Control Points.

and the four-fold block. Finally, all versions were treated by a least-squares interpolation technique.

The main result of the test is the planimetric accuracy of the 4-fold block. As RMS errors the following values were obtained:

μ_{xy} = 3.5 cm = 4.5 µm after block adjustment
μ_{xy} = 2.7 cm = 3.4 µm after least-squares interpolation.

These results are highly satisfactory and meet the planning specifications of 3 cm.

In order to get some information about the distribution of the accuracy within the block, the residual errors at the check points were plotted in vector diagrams. Figure IV-5 shows the vector diagram after the block adjustment. In this diagram some systematic trends of the residuals can be seen. Figure IV-6 shows the corresponding vector diagram after a least-squares interpolation. Here, the systematic trends have been considerably reduced, but they are still visible. I.e., some systematic error effects are still uncompensated for.

Besides the RMS errors, also the maximum residual errors are of great importance. For the 4-fold block this maximum residual error amounted to 10.6 cm $\widehat{=}$ 13.6 µm. This value is in general agreement with expectation, but it seems to be not very satisfactory for geodetic networks. The maximum residual errors could

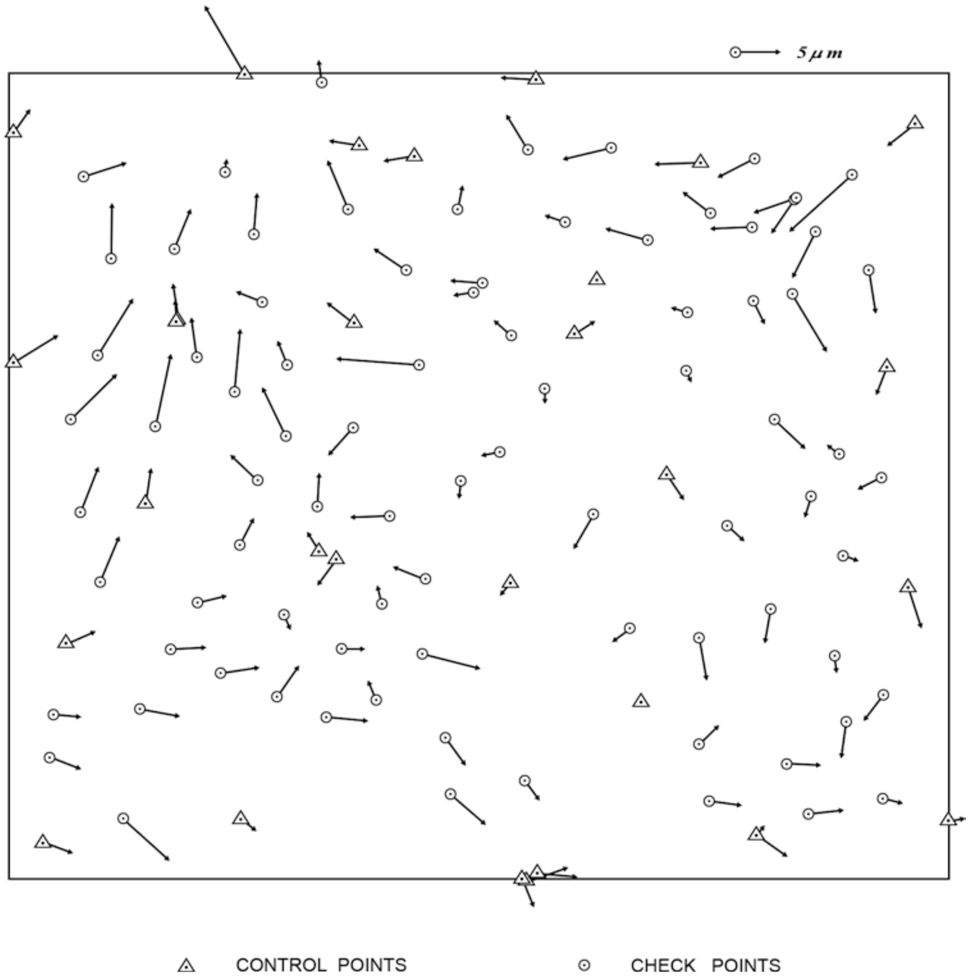


Figure IV-5. Appenweier 4-fold Block after Block Adjustment.

be reduced only slightly by least-squares interpolation to 9.4 cm ≙ 12.1 µm.

In table IV-1 the complete results for all block adjustments are summarized. When comparing the different overlaps the following accuracy relations are achieved for single, double and 4-fold blocks:

μ_{xy} = 5.3 cm : 4.3 cm : 3.5 cm after block adjustment
μ_{xy} = 4.4 cm : 3.5 cm : 2.7 cm after interpolation.

This is equivalent to the relation

1 : 1/1.25 : 1/1.6

which is less than the theoretically expected ratio of about the factor 1.5 per step. The reason must be the presence of still uncompensated systematic image errors disturbing the accuracy law based on random errors only.

The results of the second block adjustment version with dense perimeter control are shown in Table IV-2. They are almost equivalent to the results of the version with all given control points. So it is once more justified to state that perimeter control is sufficient for planimetric block adjustment.

The last comment concerning planimetric accuracy shall be related to the compensation of systematic errors. As mentioned above, all blocks were treated by

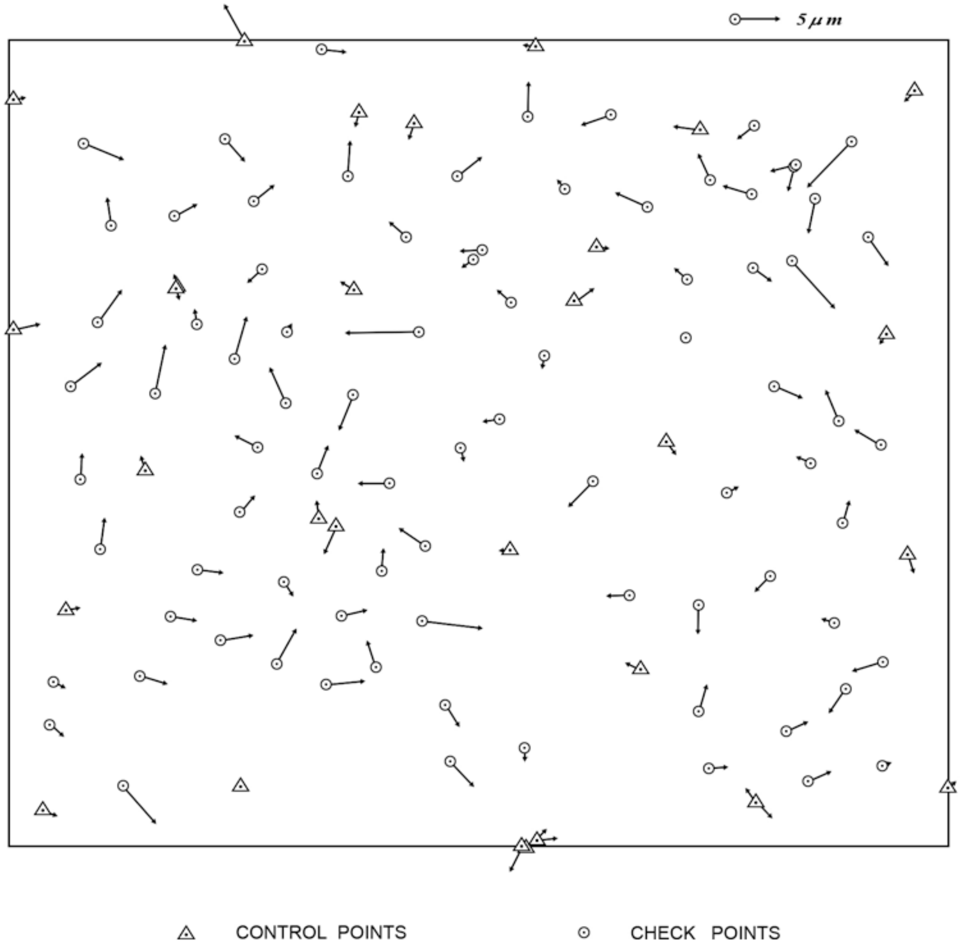


Figure IV-6. Appenweier 4-fold Block after Least-Squares Interpolation.

least-squares interpolation, because at the time when the test was performed no block adjustment program with independent models and self-calibration was available. Anyway, at the Photogrammetric Institute a preliminary program version with self-calibrating existed which was suited to treat one of the single blocks with this method.
In Table IV-3 the results are compared with the least-squares interpolation. The RMS error after self-calibration is only slightly smaller than that after a least-squares interpolation. But there is a significant reduction of the maximum residual error from 19.7 cm to 13.1 cm. So, in general, the method of self-calibration seems to be more effective than the post-treatment of the coordinates by a least-squares interpolation, i.e. after the block adjustment.

Results of vertical block adjustment

For the investigation of the height accuracy a control point distribution was used which formed a regular grid with an interval of about 4 base lengths, as can be seen in Figure IV-4. With the single blocks an RMS error of

μ_z = 10.6 cm = 0.89×10^{-4} of h was achieved, and with the 4-fold block
μ_z = 7.5 cm = 0.63×10^{-4} of h (see Table IV-4).

Similar to the planimetric accuracy the theoretical ration of at least 1:2 between the

Table IV-1. Appenweier, Planimetric Results of Block-Adjustment with Independent Models (Wide Angle, Photoscale 1:7800) All Given Control Points used (Perimeter + Points Inside)

Block	after block-adjustment										after least squares interpolation							
	σ_0	μ_x	μ_y	μ_{xy}	ε_{max}	σ_0	μ_x	μ_y	μ_{xy}	ε_{max}	μ_x	μ_y	μ_{xy}	ε_{max}	μ_x	μ_y	μ_{xy}	ε_{max}
	– cm –					– µm –					– cm –				– µm –			
Single blocks (112 models, 27 control points, 77 check points)																		
EW	3.5	4.0	5.3	4.7	12.8	4.5	5.1	6.8	6.0	16.4	3.2	4.7	4.0	13.3	4.1	6.0	5.1	17.1
WE	3.8	5.4	6.5	6.0	19.1	4.9	6.9	8.3	7.6	24.5	4.5	5.3	4.9	16.3	5.8	6.8	6.3	20.9
NS	3.4	4.7	3.5	4.1	12.8	4.4	6.0	4.5	5.3	16.4	4.0	3.1	3.6	9.9	5.1	4.0	4.6	12.7
SN	3.8	6.0	6.1	6.1	20.3	4.9	7.7	7.8	7.8	26.0	5.1	4.2	4.7	19.7	6.5	5.4	6.0	25.3
mean	3.6	5.1	5.5	5.3	20.3	4.7	6.5	7.1	6.8	26.0	4.3	4.4	4.4	19.7	5.5	5.6	5.6	25.3
Double blocks (224 models, 30 control points, 82 check points)																		
WE/NS	3.8	3.8	4.1	4.0	12.6	4.9	4.9	5.3	5.1	16.2	3.1	3.3	3.2	13.1	4.0	4.2	4.1	16.8
EW/SN	3.7	4.2	5.1	4.7	14.3	4.7	5.4	6.5	6.0	18.3	3.6	3.7	3.7	12.2	4.6	4.7	4.7	15.6
mean	3.8	4.0	4.6	4.3	14.3	3.9	5.1	5.9	5.5	18.3	3.4	3.5	3.5	13.1	4.3	4.5	4.4	16.8
4-fold block (WE/EW/NS/SN ; 448 models, 30 control points, 83 check points)																		
	3.8	3.4	3.6	3.5	10.6	4.9	4.4	4.6	4.5	13.6	2.7	2.6	2.7	9.4	3.5	3.3	3.4	12.1
1)	3.8	3.3	3.2	3.3	10.6	4.9	4.2	4.1	4.2	13.6	2.6	2.4	2.5	9.2	3.3	3.1	3.2	11.8

μ_x, μ_y = r.m.s. values of residual errors at check points ; $\mu_{xy} = \sqrt{(\mu_x^2 + \mu_y^2)/2}$; ε_{max} = max. residual coordinate error of check points

1) 8 additional perimeter control points, 75 check points

Table IV-2. Appenweier, Planimetric Results of Block-Adjustment with Independent Models (Wide Angle, Photoscale 1:7800) Dense Perimeter Control

Block	after block-adjustment										after least squares interpolation							
	σ_0	μ_x	μ_y	μ_{xy}	ε_{max}	σ_0	μ_x	μ_y	μ_{xy}	ε_{max}	μ_x	μ_y	μ_{xy}	ε_{max}	μ_x	μ_y	μ_{xy}	ε_{max}
	– cm –					– µm –					– cm –				– µm –			
Single blocks (112 models, 25 control points, 79 check points)																		
EW	3.5	3.9	4.8	4.4	12.5	4.5	5.0	6.2	5.6	16.0	3.4	4.4	3.9	12.0	4.4	5.6	5.0	15.4
WE	3.8	5.9	6.1	6.0	21.7	4.9	7.6	7.8	7.7	27.8	5.7	4.8	5.3	20.3	7.3	6.2	6.8	26.0
NS	3.4	4.2	3.8	4.0	11.6	4.4	5.4	4.9	5.2	14.9	3.6	3.3	3.5	10.1	4.6	4.2	4.4	12.9
SN	3.9	6.0	5.2	5.6	19.3	5.0	7.7	6.7	7.2	24.7	5.1	4.1	4.6	18.4	6.5	5.3	5.9	23.6
mean	3.7	5.1	5.0	5.1	21.7	4.7	6.5	6.4	6.5	27.8	4.6	4.2	4.4	20.3	5.9	5.4	5.7	26.0
Double blocks (224 models, 28 control points, 84 check points)																		
WE/NS	3.8	3.3	4.0	3.7	12.5	4.9	4.2	5.1	4.7	16.0	3.3	3.2	3.3	13.0	4.2	4.1	4.2	16.7
EW/SN	3.7	4.2	4.3	4.3	14.0	4.7	5.4	5.5	5.5	17.9	3.6	3.3	3.5	12.4	4.6	4.2	4.4	15.9
mean	3.8	3.8	4.2	4.0	14.0	4.9	4.9	5.4	5.2	17.9	3.5	3.3	3.4	13.0	4.5	4.2	4.4	16.7
4-fold block (WE/EW/NS/SN ; 448 models, 28 control points, 85 check points)																		
	3.8	3.1	3.3	3.2	10.4	4.9	4.0	4.2	4.1	13.3	2.6	2.4	2.5	7.7	3.3	3.1	3.2	9.9

Table IV-3. Appenweier, Block SN
Wide Angle. 112 Models, 1:7800
Correction of Systematic Errors.

	σ_0	$\mu_{x,y}$	ε_{max}	σ_0	$\mu_{x,y}$	ε_{max}
		– cm –			– µm –	
I	3.8	6.1	20.3	4.9	7.8	26.0
II	(3.8)	4.7	19.7	(4.9)	6.0	25.3
III	2.9	4.4	13.1	3.7	5.6	16.8

I: Block adjustment (PAT-M 43)
II: I + Least-squares interpolation
III: Self-calibrating block adjustment

Table IV-4. Appenweier; Height Accuracy After Block Adjustment with Independent Models, Wide-Angle Photography, H = 1193 m, Photo Scale 1:7800, Height Control Grid of 4 Base Lengths.

BLOCK	$\sigma_{0,H}$	RMS HEIGHT DIFFERENCES μ_Z		ε_{MAX}
	CM / µM	CM / µM	‰H	CM / µM
SINGLE BLOCKS: 112 MODELS, 138 HEIGHT CONTROL POINTS +) 60 CHECK POINTS				
EW	5.7 / 7.3	10.2 / 13.1	0.085	23.2 / 29.9
WE	6.0 / 7.7	11.6 / 14.9	0.097	27.4 / 35.1
NS	5.9 / 7.6	8.9 / 11.4	0.075	23.8 / 30.5
SN	6.0 / 7.7	11.4 / 14.6	0.096	30.3 / 38.8
MEAN		<u>10.6</u> / 13.6	0.089	
TWO-FOLD BLOCKS: 224 MODELS, 151 HEIGHT CONTROL POINTS +) 64 CHECK POINTS				
WE/NS	6.5 / 8.3	9.1 / 11.7	0.076	21.3 / 27.3
EW/SN	6.2 / 7.9	9.1 / 11.7	0.076	23.2 / 29.7
MEAN		<u>9.1</u> / 11.7	0.076	
FOUR-FOLD BLOCK (WE/EW/NS/SN): 448 MODELS, 153 HEIGHT CONTROL PTS +), 65 CHECK POINTS				
	6.4 / 8.2	<u>7.5</u> / 9.6	0.063	15.7 / 20.1

+) IN GROUPS OF 3 POINTS EACH

single and the 4-fold block could also not be reached in height. Anyway, the height accuracy itself can be considered very satisfactory.

Additional investigations

For further investigations one single block (north-south) was used. The first part of this investigation was related to the difference between glass and film diapositives, and the second part tested the influence of the number and of the type of tie points over the accuracy of the block adjustment. The results are summarized in Table IV-5 while the corresponding distribution of the tie points is shown in Figure IV-7. When comparing the results of glass and film diapositives, there is no difference in the planimetric accuracy and only a slight difference in the height accuracy. This is true for the results after block adjustment as well as after a least-squares interpolation. So, in practice, film and glass diapositives can be treated as equally accurate.

Table IV-5. Appenweier, Block NS (Wide-Angle, 112 Models, 1:7800) Influence of Model Connections over the Planimetric and Height Accuracy of the Block.

TYPE OF DIA-POSITIVE	CHECKPOINT VERSION	AFTER BLOCK ADJUSTMENT						AFTER LEAST SQUARES INTERPOLATION PLANIMETRY	
		PLANIMETRY			HEIGHTS				
		σ_0	μ_{xy}	ε_{max}	σ_0	μ_{xy}	ε_{max}	μ_{xy}	ε_{max}
FILM	SIGNALIZED	(ALL VALUES IN UNITS OF µm)							
	1.2 (18)	4.4	5.3	16.4	7.6	11.4	30.5	4.7	12.7
GLASS	SIGNALIZED								
	1.1 (18)	4.4	6.9	19.2	7.8	12.3	41.0	4.7	11.7
	1.2 (12)	4.4	6.4	16.7	7.9	14.1	42.3	5.1	15.0
	1.3 (6)	4.4	6.9	22.9	8.8	15.1	43.6	6.0	19.7
	1.4 (4)	4.5	6.7	25.5	9.2	16.3	46.1	6.4	25.5
	NATURAL								
	2.1 (6)	4.9	6.9	21.2	8.8	14.6	43.6	6.2	21.0
	2.2 (4)	4.6	6.9	21.5	8.7	16.9	52.6	6.4	18.8
	ARTIFICIAL								
	3.1 (24)	7.2	13.7	37.8	10.6	13.0	37.2	7.7	28.2
	3.2 (12)	7.1	11.8	32.7	10.4	16.2	44.9	8.2	28.1
	3.3 (12)	7.6	11.9	43.6	10.1	14.7	41.0	8.8	37.9
	3.4 (6)	7.2	11.0	42.3	10.0	18.8	51.3	9.2	40.4
	3.5 (4)	7.2	11.0	40.4	10.0	19.5	56.4	9.76	39.2

For the investigation of the tie-points three different types of points were used, i.e. targeted, natural and articially marked points. Comparing signalized and natural tie points, the accuracy of the block adjustment is almost exactly the same in planimetry and height. But with artificial points the accuracy decreases, as expected, by some 50% in planimetry and up to about 30% in height. The latter result is contradictory to other investigations with the Oberschwaben test material. It may have been caused by residual calibration errors of the point transfer instrument.

BLOCK ADJUSTMENT VERSIONS

1. TARGETED TIE POINTS
   - 1.1 18 VP IN 6 GROUPS
   - 1.2 12 VP, 4 GROUPS IN CORNERS
   - 1.3 6 VP, 1 POINT PER GROUP
   - 1.4 4 VP IN CORNERS

2. NATURAL TIE POINTS
   - 2.1 6 VP, 3 POINTS EACH AT TOP AND BOTTOM OF MODEL
   - 2.2 4 VP IN CORNERS

3. ARTIFICIAL TIE POINTS
   - 3.1 24 VP, 6 GROUPS & 6 INDIV. POINTS
   - 3.2 12 VP, 1 POINT PER GROUP & 6 INDIVIDUAL POINTS
   - 3.3 12 VP, 4 GROUPS IN CORNERS
   - 3.4 6 VP, 1 POINT PER GROUP
   - 3.5 4 VP IN CORNERS

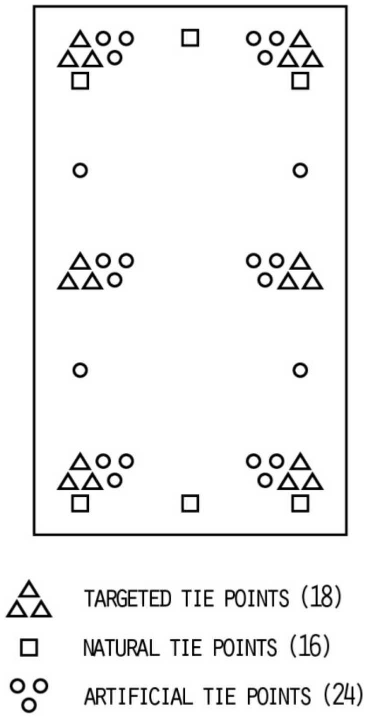


Figure IV-7. Appenweier, Block NS, Glass-Diapositives
Types and Arrangements of Tie Points (VP)

It has to be mentioned that the presently available point transfer equipment has been designed for an accuracy level of about 20 µm (RMSE of the model coordinates) and not of less than 10 µm which can be achieved today.

As far as the quantity of tie points between different models is concerned, there is a significant relation between the number of tie points and the accuracy obtained from the block adjustment. After a least-squares interpolation the accuracy increases almost linearly with the increasing number of tie points. This is not true prior to this interpolation, so that a stronger connection between the models seems to cause larger systematic errors.

Conclusion

The pilot project Appenweier has been finished as far as the collaboration with the state survey office of Baden-Württemberg is concerned. Presently these authorities do not intend to introduce photogrammetric methods for their densification works. The main reasons for this decision seem to be the maximum coordinate residuals and the economy of the method.

The maximum coordinate residuals of about 10 cm are considered unsatisfactory. With terrestrial methods the coordinate accuracy is supposed to be about 2 cm with maximum errors of the same magnitude (which never has been really proven!). In addition, the terrestrial method is told to be more economic than the photogrammetric one.

The last statement may be true when considering only this special test project Appenweier. Here, the ratio between the number of points to be determined and the number of models in the photogrammetric block was about 1:5. This means that 5 models are required to determine 1 point which is equivalent to a distribution of about 1 point per km^2.

The photogrammetric method would, of course, become more economic if the number of points to be determined is increased, and if the accuracy requirements are changed to about 5 cm, instead of 3 cm. In addition, in practical projects it is not possible nor necessary to signalize all tie points, which would also favorably influence the economy of the method.

Finally, it may be mentioned, that the Photogrammetric Institute intends to perform some more investigations with this material, especially as far as block adjustment with self-calibration is concerned. These investigations shall mainly deal with bundle block adjustment with additional parameters. It is expected that in this case the accuracy requirements can be met already with the double block or with 60% side overlap.

Waldhäusl

In Austria we fly for network densification at a scale of 1:8000, wide angle camera, and normally there is a point density of 10 points per km^2.

Dorrer

As I understand from the presentation, this number of one point per model is for the 4-fold block.

Stark

It is for the 4-fold, yes, but we had to choose the 4-fold overlap because of the accuracy specifications of 3 cm.

Waldhäusl

In Austria, for photogrammetrically determined network points, an RMS error $m = \sqrt{m_x^2 + m_y^2} = 7$ cm is specified.

Stark

Our 3 cm are for the coordinates, i.e. x <u>or</u> y.

Waldhäusl

To compare this figure with the Austrian 7 cm, we must say 5 cm.

Grün

You do not need a 4-fold block if you have a bundle triangulation program with self calibration. A single block would be sufficient if you use 60% side lap.

Mauelshagen

"RHEIDT" TEST FIELD ANALYSIS

Under the topic I want to show you briefly the principles of test field calibration and some results of the test "Rheinbach". A functional model of the photogrammetric imaging process or of system components is to some extent only valid for a camera system under actual flight conditions and for a certain photographic process. Therefore, it is a main aim to check this model under real flight conditions and to detect systematic imaging errors. The detection and elimination of systematic image coordinate errors is necessary, for these errors falsify the adjusted strip or block. One method for the effective handling of systematic errors is the partial calibration by means of a test area /5/.

The flat Rheidt test field (2 km by 2 km) has been in use for over ten years. It contains 41 groups of points with 3 points in good alignment and most of the tie points with 3 m distances within a group. Each point is targeted with a white plastic sheet 30 cm by 30 cm. The distribution of point groups is uniform /1/. Having used electronic distance measurement, triangulation (theodolite observations) and levelling, the standard coordinate errors of all points lie within <u>10 mm</u>. The principle of partial calibration is based on the refinement of the mathematical model of the bundle block adjustment (in this case) in order to detect and eliminate systematic image errors. This refinement is carried out by incorporating and computing additional parameters in a simultaneous adjustment of the test flights (self calibration). There are incorporated diverse correction parameters in the bundle-program BOBUE/ Institute of Photogrammetry Bonn: residual radial distortion, decentering distortion, affinity, shearing and unflatness of the camera platen /5/, /6/.

The influence of the earth curvature, of the standard photogrammetric refraction and of the radial distortion (inspection slip) are taken into consideration a priori.

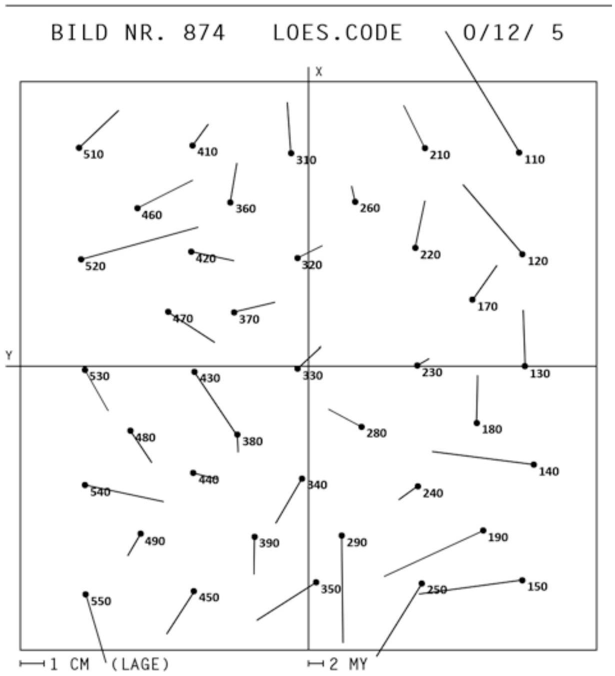
In the results following afterwards, a partial third order polynomial has been taken as additional parameter.

Short periodical systematic image deformation can be determined by test flights before and after the project flights and can be incorporated in the image coordinates before the analytical triangulation is performed. The stationarity of systematic errors during longer periods of time can be supervised, too.

An example shows the effectiveness of additional parameters in the image plan (Fig. IV-8 and IV-9). The corrections are derived from the observation equations after a simultaneous bundle adjustment. Without additional parameters the plotted corrections show some sort of affinity, which will be destroyed by additional parameters.

The image scale of the 4 flights was approx. 1:10 500. Three photos per strip were chosen with 60% forward overlap. The whole test area was covered stereoscopically. The bundles were tied to 5 full control points, one in each corner and one in the center of the area. Each strip had an alternating flight direction at ± 90°.

Another example shows the high accuracy of the photogrammetric determination of check point coordinates of the test area (Fig. IV-10 and IV-11, cf. /3/).



Figuire IV-8. Corrections of Image Coordinates after Bundle Adjustment without Additional Parameters. (σ_o = 6.1 μm)

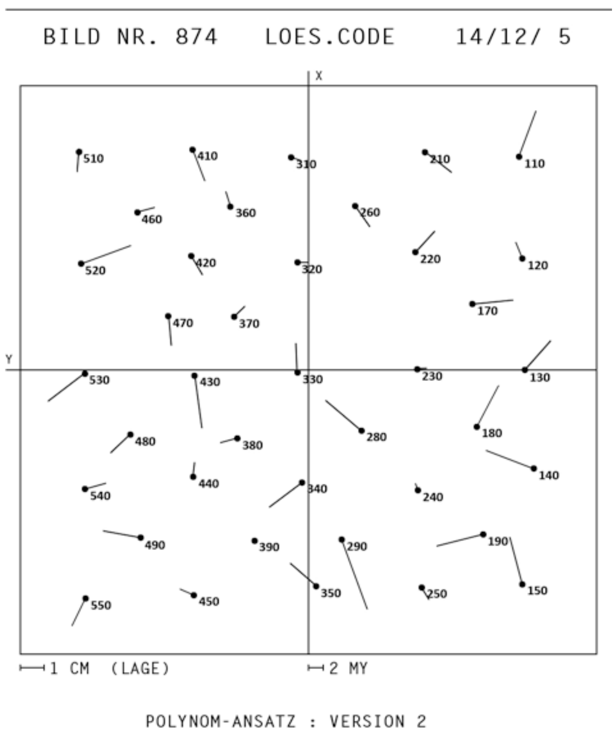


Figure IV-9. Corrections of Image Coordinate after Bundle Adjustment with Additional Parameters. (σ_o = 3.8 μm)

●		17		13		17		●
	16		15		13		15	
16		13		9		13		15
	14		x		12		14	
12		11		●		12		14
	15		12		11		13	
14		12		8		12		15
	14		13		12		14	
●		15		12		15		●

Figure IV-10. Photogrammetric Standard Errors of Elevation (σ_z). From Simultaneous Adjustment of RC 8 and RMK Photography. Standard Errors refer to mean Coordinate Values of each Point Group. Black Dots = Control Points. Values in mm. cf. /3/.
(σ_o = 4.0 μm)

●		7/10		6/8		7/9		●
	8/7		6/7		6/7		8/7	
11/6		6/6		5/5		6/6		9/6
	8/5		x		5/5		7/5	
8/5		5/5		●		6/5		9/5
	8&7		5/5		5/5		7/5	
9/6		6/5		5/5		6/6		9/6
	8/6		6/6		6/6		7/6	
●		7/8		6/8		7/8		●

Figure IV-11. Photogrammetric Standard Errors of Planimetry (σ_x/σ_y). Details Fig. IV-10.

These results were obtained by a simultaneous bundle adjustment of 3 flights, 4 strips each, with RC 8/Wild and RMK 15/23/Zeiss. 4 strips taken with RC 8 and 8 strips taken with RMK at a scale of 1:11 000, and 2 strips taken with both cameras at 1:5 500 have been combined in this adjustment. There were approximately 4900 redundant observations. Radial and decentering distortion, and a third order polynomial have been incorporated as additional parameters. The State Survey Office of Nordrhein-Westfalen and the Institute of Photogrammetry of the University of Bonn collaborated in the test triangulation "Rheinbach", near Bonn. The geodetic triangulation network of fourth order was to be checked and the application of aerial triangulation methods to its densification was to be tested. The network was inhomogeneous and of poor geometrical quality. "To overcome this situation the Department of Trigonometry of the State Survey Office observed precision traverses including the already established trigonometric points at the perimeter of the area, followed by filling the interior of the area by a readjustment of the point coordinates using the observations of the old network" /4/.

The almost flat area forms a rectangle of 8 km by 10 km. Two flights with perpendicular directions of strips were performed by Rheinische Braunkohle AG with 90% forward overlap and 20% side lap using a Zeiss RMK 15/23 (Fig. IV-12, cf. /4/).

All points to be measured at the Institute's Zeiss PSK have been targeted by white plastic sheets 30 cm by 30 cm, including tie points, trigonometric points and control points.

Immediately before and after these Rheinbach flights the Rheidt test area was flown. For Rheidt each flight contained 4 strips, each with alternating flight directions at ± 90°.

All photos were taken on the same role of film at a scale of 1:11 000. Thus the whole photogrammetric system was identical.

"In planimetry all points of the above mentioned precision traverses served as control for aerial triangulation, whereas the readjusted coordinates of the trigonometric points within the area were considered as check points" /4/, (19 horizontal control points at the block perimeter, distance approx. 2 km or 2 base lengths).

"As all elevations of the remaining points are computed from trigonometric observations only, their use a check points is even more limited than it is with planimetry" /4/, (17 vertical control points with more or less random distribution).

To detect systematic image coordinate errors, correction-polynomials were computed simultaneously for the 8 strips of the Rheidt test area (24 photos) /2/.

The image coordinates were corrected a priori for radial distortion (inspection slip), earth curvature and standard refraction.

Table IV-6 and figures IV-13 to IV-16 show the results of the triangulations.

Regarding geodetic control points as free of error, the inner accuracy of aerial triangulations can be calculated from the coordinate differences d for the triangulated points of two independent blocks.

$\overline{\mu}^2 = \frac{\Sigma d^2}{2n}$, Photogrammetric accuracy, determined for a single block; n = number of coordinates.

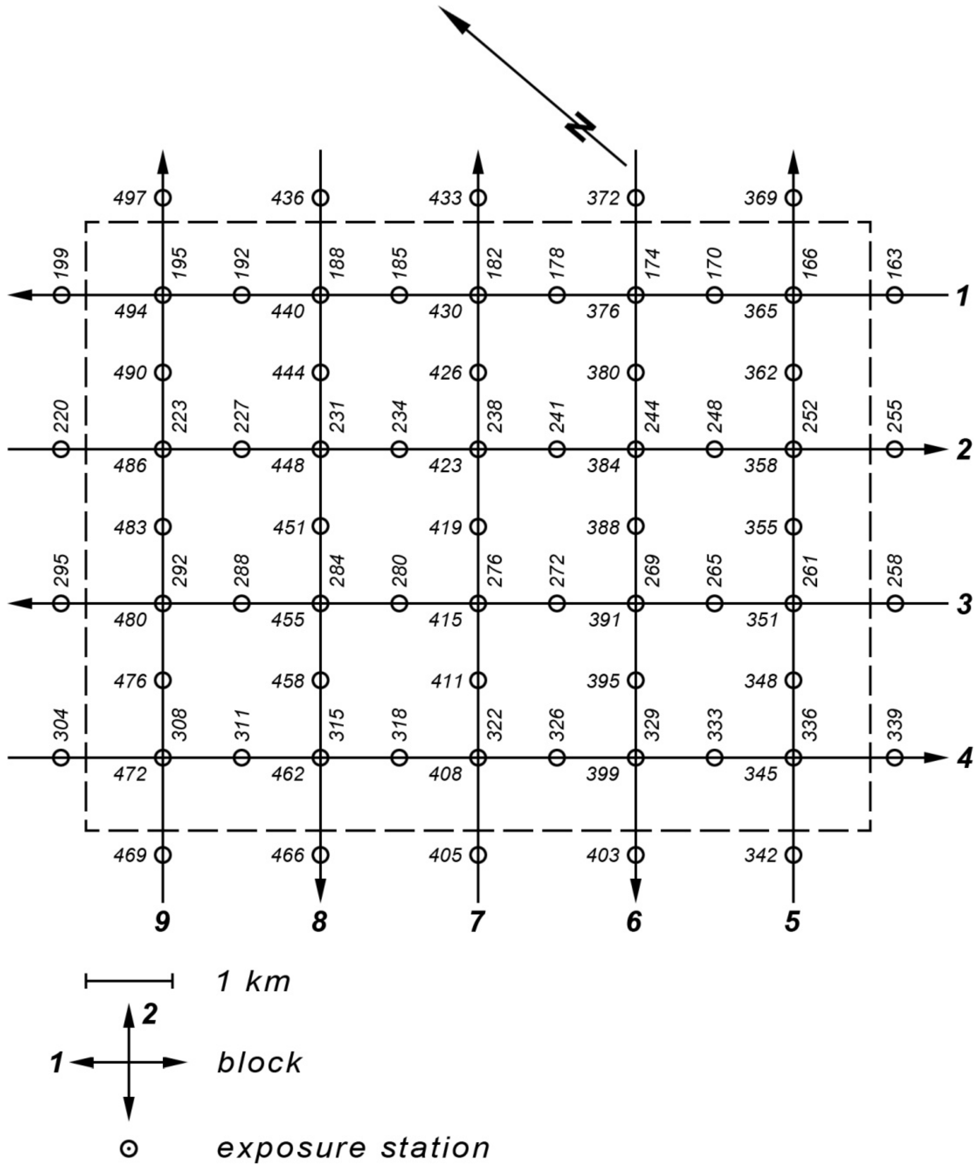


Figure IV-12. Flight Lines for "Rheinbach" Area. cf. /4/

Table IV-6 shows standard errors of unit weight (quadratic means of both blocks) and resulting $\overline{\mu}$. There is an increase of accuracy for triangulation with field calibrated image coordinates, above all concerning the $\overline{\mu}$.

Figure IV-13 and IV-14 represent vector-plots of differences, d, for planimetry and elevation resulting from the bundle triangulations. There are two sets of vectors: the right one is plotted by applying field calibration, the left one without applying it. Control points are circled. After having carried out a partial inversion of the normal equations by the BOBUE-program the standard errors of the coordinates are as follows:

$\sigma_p = \sigma_o \sqrt{Q_{xx} + Q_{yy}}$, standard point error in planimetry

$\sigma_z = \sigma_o \sqrt{Q_{xx}}$, standard error in elevation.

Table IV-6. Aerial Triangulation Rheinbach. Standard Errors of Unit Weight and Internal Photogrammetric Accuracy derived from two Independent Blocks. Improvement of Accuracy by Field Calibration is given in Percentage of Results without Refinement. Photo Scale about 1:11 000. cf. /2/.

BUNDLE TRIANGULATION		
	without field calibration	with field calibration
σ_0 (µm)	4.3	3.8
Improvement %	–	12
$\bar{\mu}_{x,y}$ (mm)	93	57
Improvement %	–	39
$\bar{\mu}_z$ (mm)	282	150
Improvement %	–	47

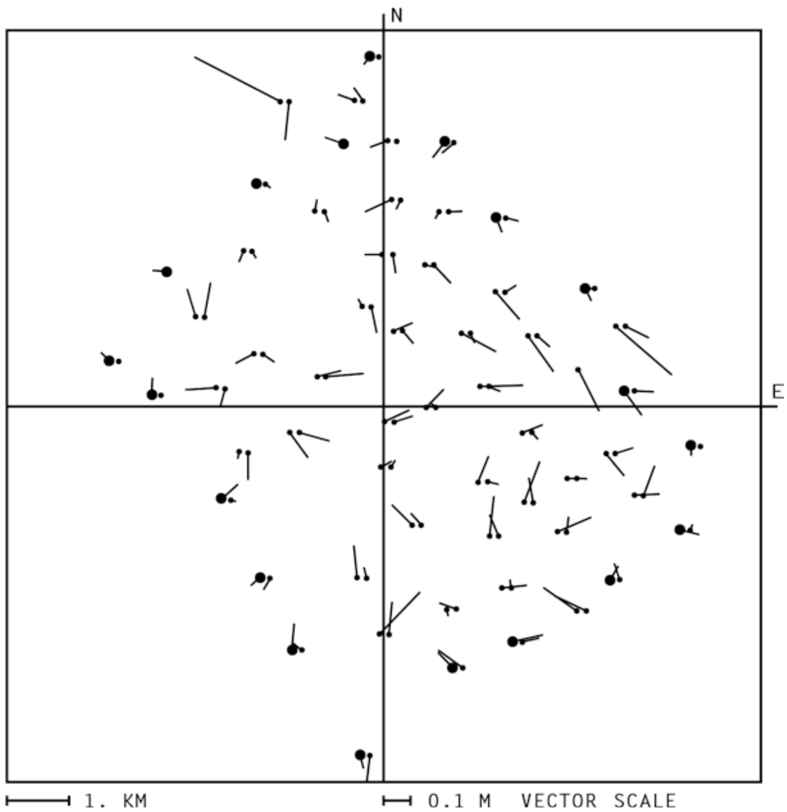
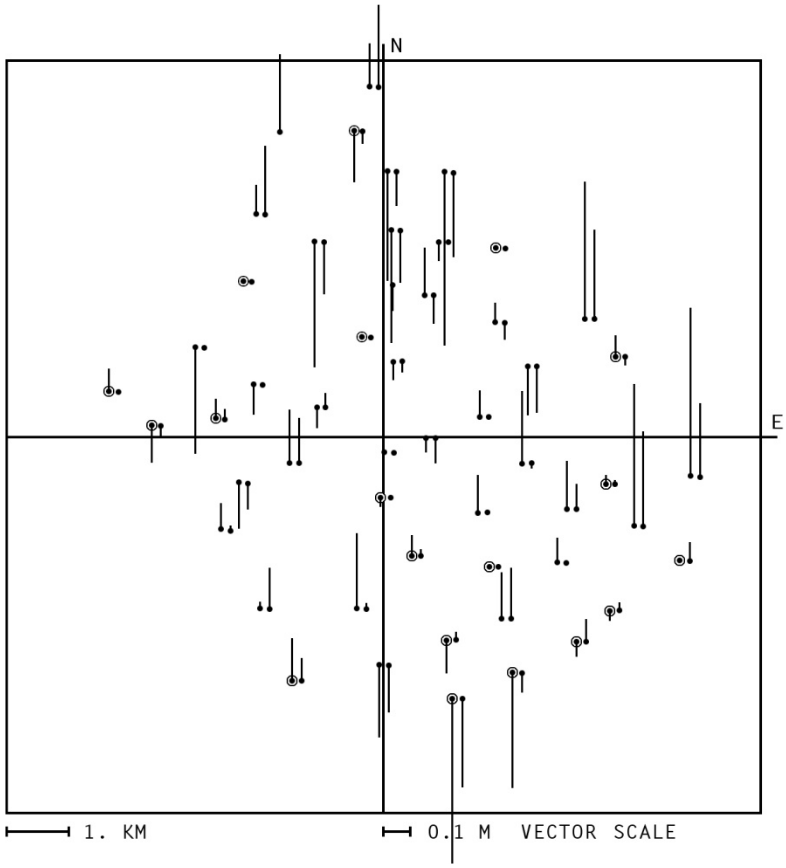


Figure IV-13.

Differences d between Photogrammetric Planimetric Coordinates from Bundle Triangulation of Block 1 and 2. Twin Points = same Check Points: Left Vector – Differences without Field Cal., Right – with Field Cal. Control Points are circled. cf. /2/.

Figure IV-14.

Differences d between Photogrammetric Elevations from Bundle Triangulation of Block 1 and 2. Details Fig. IV-10.



In Figures IV-15 and IV-16 the standard errors of coordinates after double block adjustment with additional parameters can be compared with the standard errors derived from the trigonometric adjustment /4/. Some photogrammetric standard errors are smaller than the trigonometric ones. In comparison with double block results, the trigonometric coordinates cannot be considered as error free any longer.

Because of some other discrepencies the State Survey Office arranged a new trigonometric adjustment as a free net. We are now at the stage to readjust the whole block for detecting the nonhomogeneities of the triangulation net.

References

/1/ *Kupfer, G.: Zur Geometrie des Luftbildes. DGK-Reihe C, Nr. 170, München 1971*

/2/ *Kupfer, G.: Improvement of analytical aerial triangulation by field calibration. Proc.ASP, Phoenix, 26-31 Oct. 1975*

/3/ *Kupfer, G.: Partial calibration of photogrammetric systems including réseau cameras using a flat test area. Pres.Paper, XIII Congress ISP, Helsinki, 11-23 July, 1976*

/4/ *Kupfer, G.: On accuracy achieved by different triangulation procedures. Pres.Paper, XIII Congress ISP, Helsinki, 11-23 July, 1976*

Figure IV-15.

Control Points, Check Points and Standard Errors in Planimetry
cf. /4/

xx Trigonometric Standard Error in mm
o
yy Photogrammetric Standard Error in mm after Double Block Adjustment with Additional Parameters.

- ● control point
- ○ check point

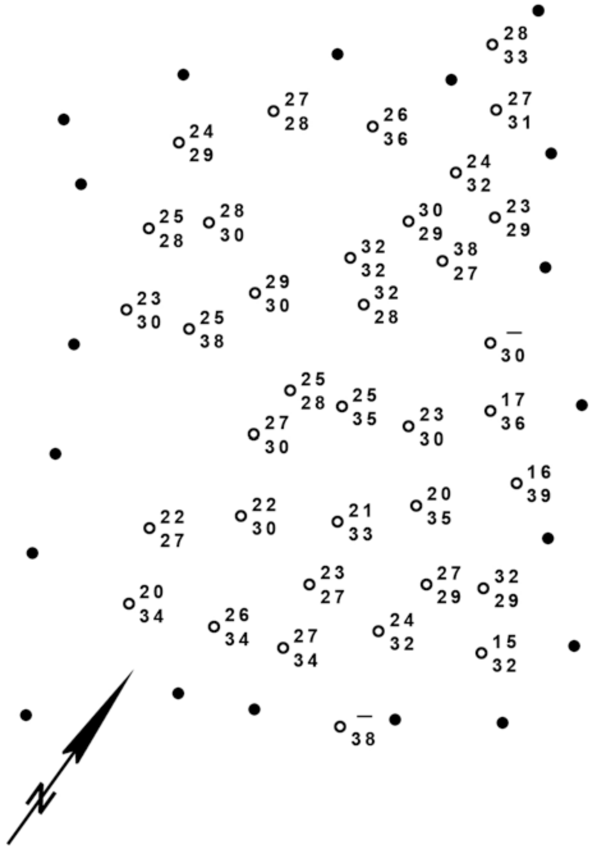
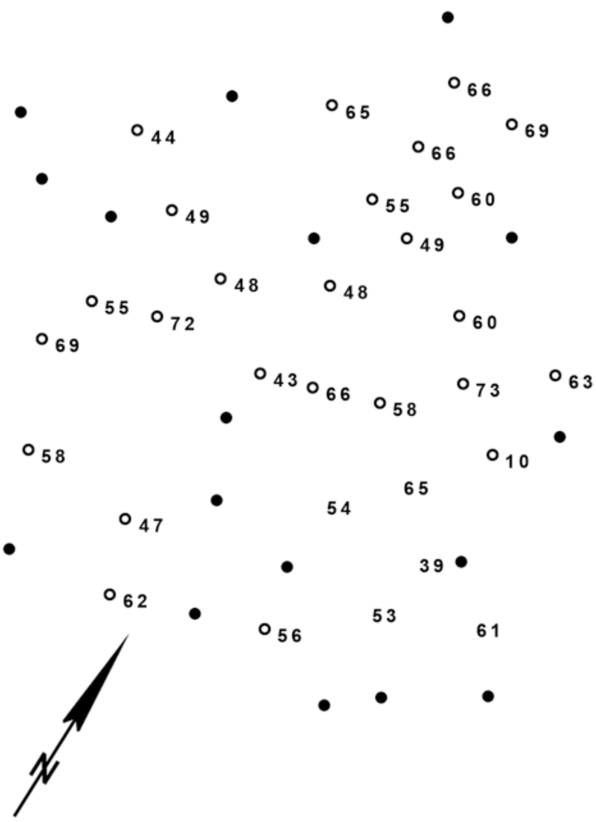


Figure IV-16.

Control Points, Check Points and Standard Errors in Elevation in mm after Double Block Adjustment with Additional Param.

- ● control point
- ○ check point



/5/ *Mauelshagen, L.: Teilkalibrierung eines photogrammetrischen Systems mit variabler Paßpunktanordnung und unterschiedlichen deterministischen Ansätzen. Dissertation 1976, Bonn, in press.*

/6/ *Mauelshagen, L.: Teilkalibrierung eines photogrammetrischen Systems unter Verwendung von Testfeldern. Pres. Paper, XIII Congress ISP, Helsinki, 11-23 July 1976*

Dorrer

The handling and elimination of systematic errors is one of the key problems which was already shown yesterday in Session II, and we shall see what we find out in Session V, when talking about the combination of photogrammetry and ground surveying.

Blachnitzky

THE PROJECT MOOSACH
(translated from German)

The Moosach project touches upon just a small part of integrated survey problems, but especially in Southern Germany this problem is a very typical and frequently occurring one. Here, most urban areas had been subject to renewals of cadastre during the last 100 years, all of them based on a network of trigonometric points and traverses. The control points are generally given in different coordinate systems, the detail points being measured by quasi-perpendiculars. Results of these renewals are cadastral plans in the scale 1:1000.

Due to war destruction and construction works, most of the control point monuments became lost, and were recovered and restored several times by the aid of the old field sheets in case of resurvey operations. Thus, the marks became more and more unreliable, and the control net was expected to lose its quality. Besides, the maps became incomplete with regard to buildings and are lacking in topographic detail.

Since the establishment of the Gauß-Krüger (UTM) System as the new and official German coordinate system, and since we are making efforts to establish a multipurpose, coordinate-based cadastre, all surveying points have to be coordinated in the UTM by new computations or by simple converting, and the map contents are to be completed. Besides, we need a new, modern network whose relative accuracy of about 2 cm is sufficient for most of the engineering projects, too. We must give it a resistant stabilization by proper marking, because otherwise it will get lost or unreliable within a short time, particularly in urban areas.

We started these operations in Munich in 1975 and chose the district of Moosach for a test field (Fig. IV-17). The main reason was that Moosach is partially bordered by good UTM-networks: East of Moosach the network for the 1972 Olympic Games constructions, north of Moosach a network for a planned goods station.

The renewal of cadastre had happened there in 1936 and had created a good, but now unreliable marked net of traverses (Fig. IV-8).

Surveying is, like any other kind of work, not only a problem of efficiency, but also one of humanity. In urban areas, ground surveys mostly are retarded, made dangerous and troublesome by the rush of traffic on streets and sidewalks. In order to avoid such circumstances, we decided to use a combination of photogrammetry and ground surveys by modern means.

The UTM-control points were well located along the perimeter (see Fig. IV-19). The old control points of 1936 were subsequently visited, and contiguous points were combined in "nests" with diameters of 30 to 50 m and average distances of 300 m. We filled up the nests by marking additional points on walls and brickwork, by shooting or adhesively sticking little targets, or using well defined house corners. Thus, if all ground points of a nest should be destroyed one day, it will be easy to determine new ones by the aid of the wall points.

In each nest, 3 or 4 suitable ground points became photo points by panelling them with painted targets. The photo flight (photo scale 1:3300) was per-

Figure IV-17. Map of Moosach District in Munich.

formed early in the morning, when the streets were trafficfree and the sidewalks were free of pedestrians. Thus, we had to avoid the parking lots only when targeting. The long, but weak shadows at dawn of a summer's day do not hinder the measurements in the stereocomparator. Then, the coordinates of over 400 points were determined by a bundle adjustment, as Dr. Grün told you yesterday.

For each of the approximately 100 nests with over 1200 points the coordinates from the bundle adjustment should give the best positions within the survey area, and should serve as junction points for other nest points. However, according to the

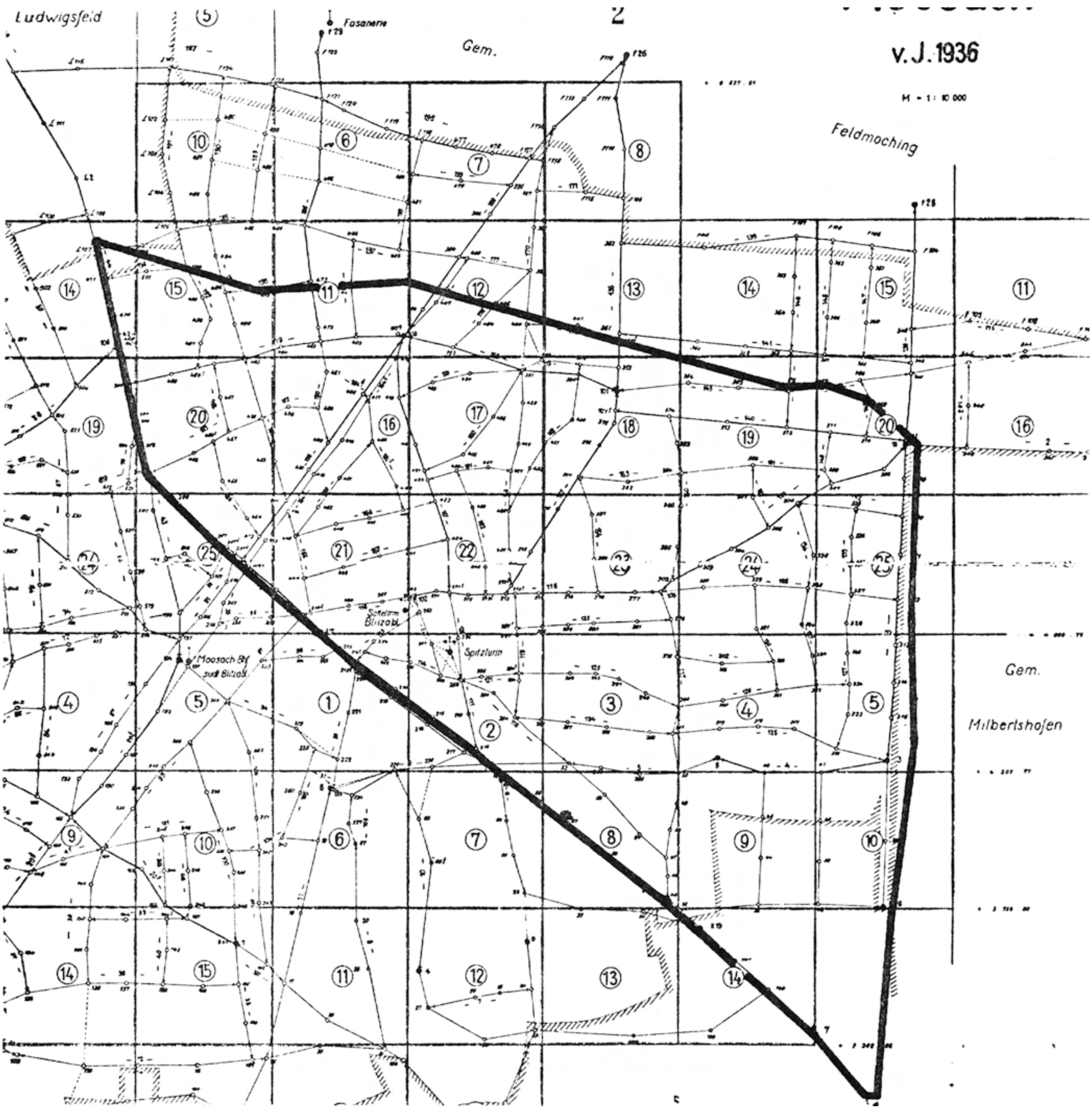


Figure IV-18.   1936 Traverse Network of Moosach with Perimeter.

principle of adjacent points, these photo points should be improved by subsequent ground surveys as well.

This ground nest survey (Fig. IV-20) was done by use of the electro-optical self-recording tacheometer RegElta of Zeiss. In each nest, 2 free stations on side-walks were chosen (triangles). From each of them, every other nest point – i.e. photo points (squares), other ground points (circles), house corners and targets in walls (semicircles) – had to be visible, and were measured by directions and distances. Because there was no need to measure long distances, we were not handicapped by the traffic.

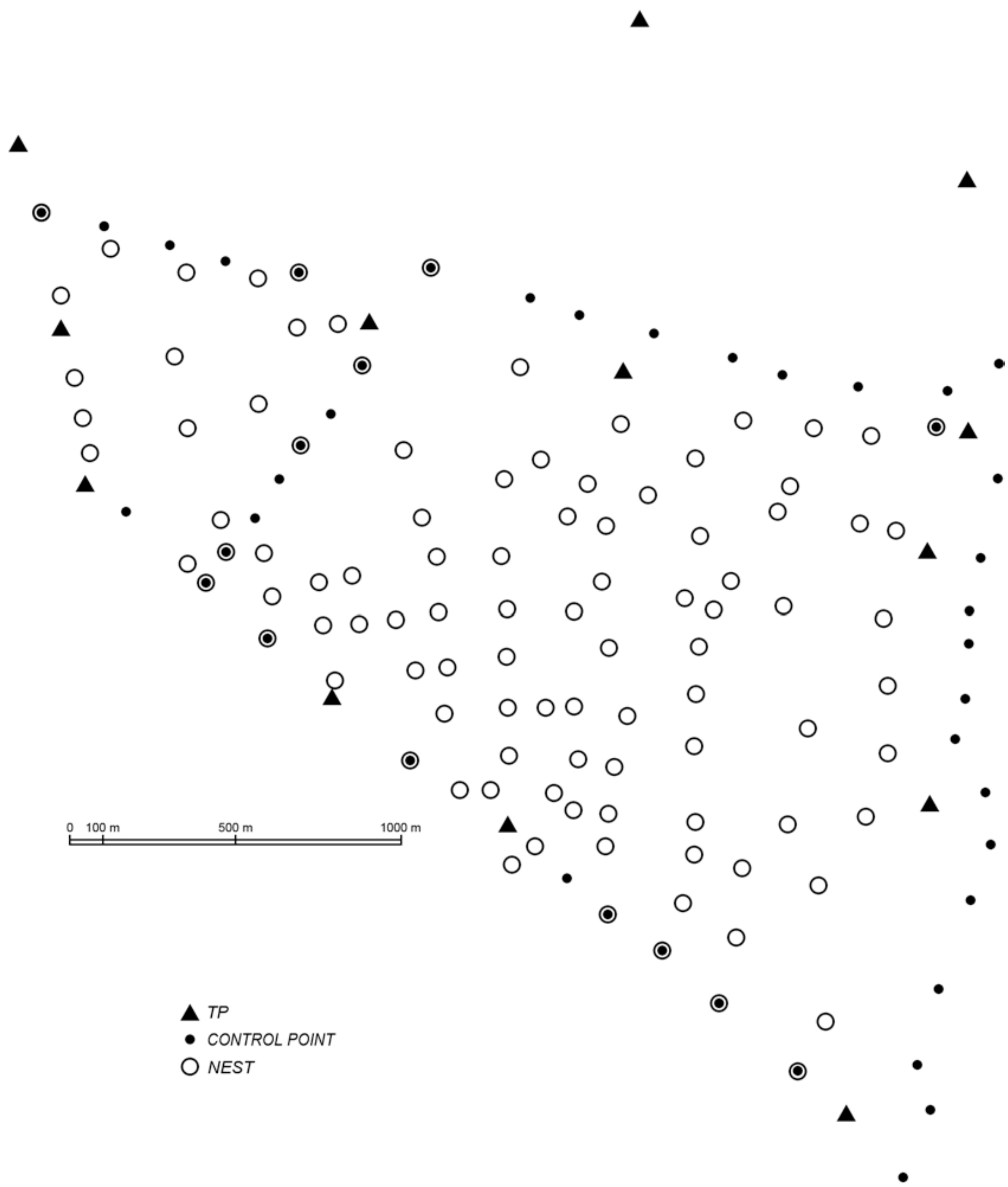


Figure IV-19. Location of Control Points and Point Nests.

The RegElta-tape, containing all data of the whole ground survey, was fed directly to the computer. Hence, all nest points including the photo points (which) were in this way control points and new points at one blow) were coordinated by parametric net adjustment. By this mode we got some additional checks for the bundle adjustment accuracy in agreement with Dr. Grün:

- 80% of the bundle adjustment coordinates changed less than 2 cm.
- the maximum change of distances between 2 photo points within a nest amounted 4 cm.
- the distances between points of neighboring nests, checked by the use of an electronic range finder, showed average differences of 1 cm, maximum 5 cm.

Thus, numerical photogrammetry once more had proven to be sufficiently precise as far as cadastral surveying is concerned. In future, we do not need any more net adjustments but simple radiation for coordinating the nest points.

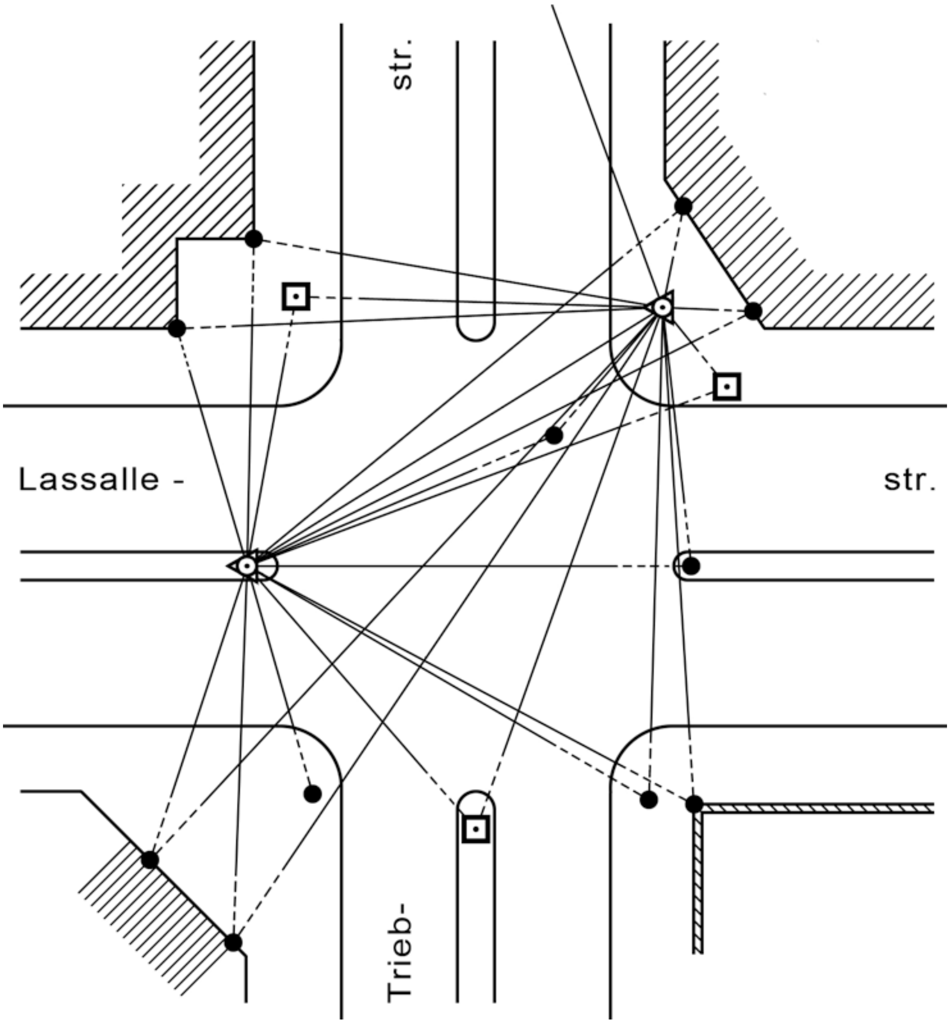


Figure IV-20. A Typical Point "Nest".

This year, we will cover another district of Munich in a purely terrestrial manner for comparison with the project Moosach. It can be said already today that, because of the troubles due to city traffic, the engaged survey teams long for the help of Photogrammetry in the "Moosach" way.

To finish our work, we checked the marks found from the 1936 control points by a Helmert transformation to get knowledge of their identity concerning their original positions. Figure IV-21 shows the residuals. About 15% of the marks found proved to be outliers as a result of poor former restorings. The other points were destined to be suitable for check points to convert the unrecovered old points into UTM-coordinates by a special kind of transformation, which operates prediction-like. The detail points at least are to be coordinated from time to time on the basis of the old quasi-perpendiculars, records and sketches. It is intended not to use any more of these old field documents when all coordinates are suitably enough available.

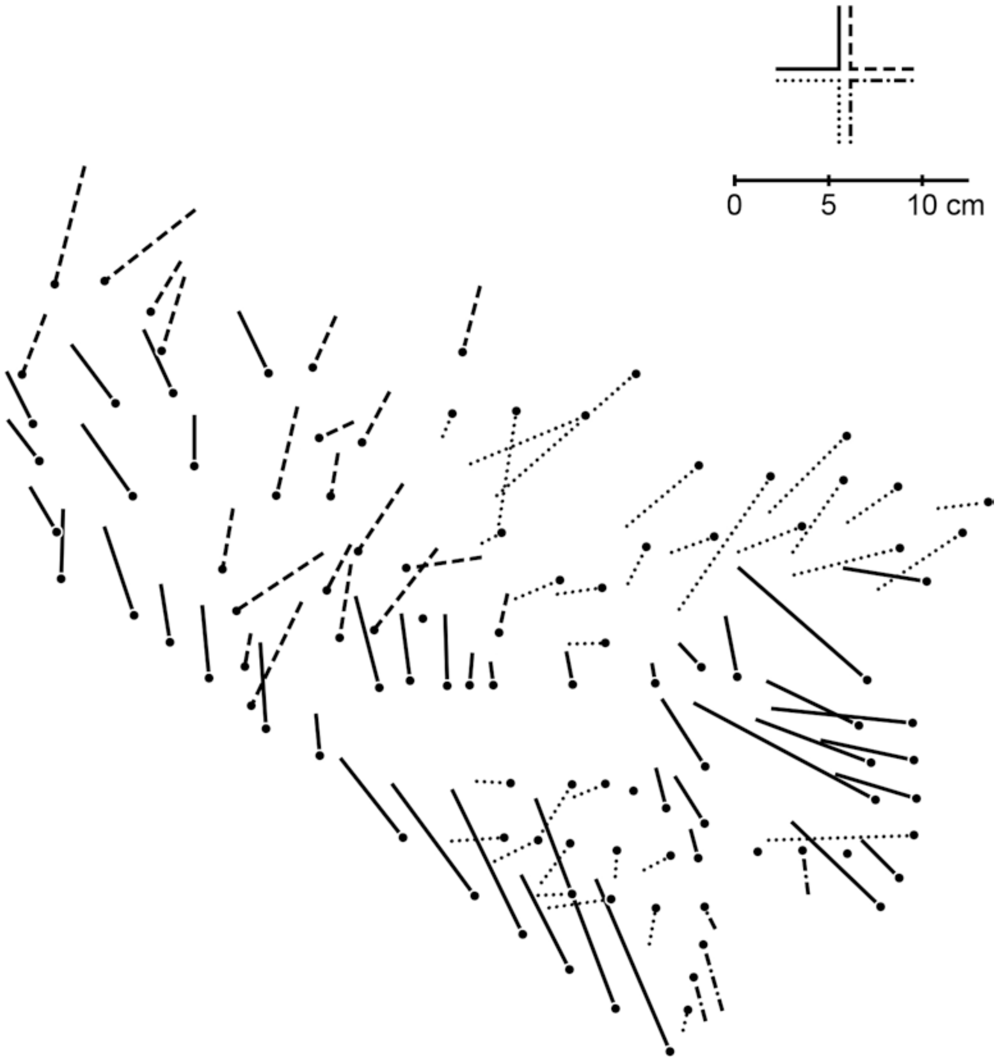


Figure IV-21. Residuals showing different Patterns according to four different Traverses.

The completion of the cadastral maps will finally be done with the aid of graphical photogrammetry. One day all features will be digitized occasionally by a necessary ground survey.

Dorrer

Gentlemen, this last picture shows that in the case of large and very large scale photography of urban areas, photogrammetry can meet rather high accuracy requirements. Also, photogrammetrically determined point fields are much more homogeneous than trigonometric networks of third and fourth order.

Blachnitzky

Yes, the ground points, being from the year 1936, contain mainly the errors of the old traverses. Due to the good photogrammetric frame, it was possible to obtain a valuable confirmation of the other points. I.e., the presented vectors indicate a strong systematic manner, while the random errors remain within the error limit. It is, therefore, possible by means of a transformation than largely eliminates this systematic effect to allocate good positions to the transformed points in the system of the well determined photogrammetric frame.

Waldhäusl

How are the wall points stabilized? We in Austria have the so-called "fork-points". Many tens of thousands of them are in use. Two "ring-bolts" (with a hole) are wall-monumented at a height of 20-40 cm above the ground. A two-armed "fork" (Fig. IV-22) defines an isosceles triangle and thus an eccentric point, whose coordinates are known. This monumentation is the most stable one in town areas according to our opinion.

Blachnitzky

We use targets with a diameter of some 4 cm, and we shoot them into the wall. We shoot about 5 or 6 marks around the point nest. You must have something like this, otherwise your nests would be lost in a short time.

Chrzanowski

I would like to add that we have a project in the City of Fredericton in Canada in which the ground monumentation is replaced by wall monuments in the control network. We monument 4 small brass plugs at each intersection, and the ground traverse is run with a free standing theodolite which can be set up in any convenient place with lines of sight not obstructed by traffic or by construction in the streets. The position of the theodolite is then determined either by a simple resection to the coordinated wall markers or by a linear intersection. We found that we are losing about 10% of the points every year in the cities, if they are monumented in the ground. Details of our project will be published in the Canadian Surveyor in the September issue (No. 3, Vol. 31, 1977): "Control Networks with Wall Monumentation: A Basis for Integrated Survey Systems in Urban Areas".

Are there any other questions to Mr. Blachnitzky?

Figure IV-22. Gabelpunkt ("fork point")
(Courtesy of Bundesamt für Eich- und Vermessungswesen, Vienna, Austria)

Stark

Have you had any problems with hidden targets so that you could not see them in the photographs?

Blachnitzky

No, no troubles.

Dorrer

Did you have any troubles with trees in the area? It was spring time, I believe.

Blachnitzky

No, it was an urban area with not too many trees.

Dörschel (Translated from German)

The flight was carried out during the summer. This is very important here, for we wanted to fly very early in the morning in order to avoid the traffic. Hence we already needed good brightness. Having decided to measure terrestrially most of the nest points later, i.e. after the flight, we were able to set out the points to be targeted such that they were safely visible in the aerial photographs. Thus, actually only highly visible points had to be signalized and evaluated. The loss of points during the photogrammetric measurement, therefore, was very low.

Dorrer

So, the main purpose of these point nests was to find at least a few points in cases where some would be obscured. Would that be right?

Blachnitzky

Yes.

Stark

Does that mean that all points of the nest have to be targeted?

Blachnitzky

No, this would be difficult for photogrammetry. Because of the nest survey we could choose the points which were always visible, as Mr. Dörschel just told you.

Waldhäusl

THE VIENNA EXPERIMENT OF THE OEEPE/C

1. Introduction

This is an interim report from the pilot centre, the Institute of Photogrammetry, University of Technology, Vienna. I shall give you a short description of the history of the experiment and its aim and results; then I will report on the photoflights, the terrestrial and photogrammetric measurements, on the reaction of the measuring centers and on the computation program envisaged for 1978.

2. The History of the Experiment

The very beginning was already seven years ago. In 1970 it was agreed upon that two new international experiments should be undertaken for a more detailed study of the capabilities of photogrammetry especially in town areas: the experiments Dordrecht and Vienna. It is something to organize any scientific experiment; but the organisation of an international experiment is more. Table IV-7 shows that it lasted three years until we got the photoflights, and another four years until I had all the 180 000 measurements from the 16 measuring centers.

3. Aim and Result of the Experiment

The task of the OEEPE-Commission C is to check objectively the obtainable accuracy from large scale single models for:

- cadastral surveys,
- network densifications,
- town surveys.

The method for these tests should be the practical experiment, internationally controlled, representative in the statistical sense, reliable and close to the practical case, as a sound basis for the standardization or calibration of theoretical studies like simulation processes.

The previous experiments were Oberriet and Reichenbach. Their purpose had been cadastral photogrammetry, including network densification. In Oberriet there were only small or no height differences, but the Reichenbach area was mountainous.

The new experiments (Dordrecht and Vienna together) should continue the Reichenbach test and include basic studies for the photogrammetric measurement of typical town elements.

The utmost urgency has been given to the problem of the roofmeasurements. Therefore, the experiment Dordrecht dealt with the question only. Its final report will be published soon.

Roofs have been excluded therefore from the Vienna experiment, which has two main objectives:

- First, it shall continue the earlier test series of Oberriet and Reichenbach, now with the photo scales 1:4 000, 1:2 500 and 1:500, i.e. large scale test series on presignalized points. The pilot centre for the time of the measurements is the Technical University of Vienna, but the computational part and final analysis will be done by the IFAG in Frankfurt.
- Second, it shall answer a number of questions concerning photogrammetric town surveys:

Table IV-7. The History of the Vienna Experiment.

Working place	year	work done by country:
Preliminary studies	1970/71	NL
Outline	1972	A
Test field	1973	A
Photoflights	1973	A
Distribution of materials	1974	A,B
Measurements received	1975-77	x)
Measuring program	1971	Comm. C
Computation program	1976	Comm. C
x) 3 A, 3 CH, 4 D, 1 DK, 1 I, 1 N, 2 NL, 1 SF		

Table IV-8. The Experiments of OEEPE Commission C.

The Experiment	Years of flights	Photo scales 1:	Terrain	Main purpose
Oberriet	1954	21 000 to 5 000	flat	Cadastre and Network densi-fication
Reichenbach	1959	12 000 and 8 000	mountainous	– " –
Dordrecht	1972	6 000 and 3 500	town	Survey of roofs
Wien	1973	4 000 to 1 500	town	Large scale and town surveys

– whether sunny or diffuse illumination gives better conditions,
– how typical town details can be measured, such as corners of houses, pavements, rails, masts, traffic signals, fences, trees, etc.

4. The Test Field

The test field is rather small (800 x 500 m), but includes more than 3000 points. The area is situated close to the Danube in Vienna and shows typical town details with streets, rails, houses, parks, railway stations, etc. In the meantime not very many points may be left because underground and bridge constructions are going on there.

5. The Photo-Flights

Table IV-9 shows the 8 photoflights, two series of four each for sunny and diffuse illumination respectively. For the first main task of the Vienna experiment, the flight with sunny and diffuse illumination of the three different scales will be compared. The two sunny flights 1:4 000 are prepared for the comparison between the results of old and new angle lenses. The sunny and diffuse versions will be compared in order to find out whether there is any systematic influence of the illumination on the accuracy of the results. And all flights will be used for the study of the accuracy of typical town detail. The 1:4 000 flight with diffuse illumination unfortunately had to be rejected because of bad photographic quality.

6. The Terrestrial Measurement

Harry has said about the results of the Oberriet experiment, where natural points have been measured more accurately by the photogrammetrists than by ground surveyors: "The mouse on the carpet cannot see the ornament as good as a man from his eagle's perspective". In other words: We have to consider that the main influence of our measurements is the point definition.

In the Vienna experiment the town detail points have been measured twice completely independently. Thus, we also have received knowledge about the influence of the terrestrial point definition and terrestrial point identification.

The first ground survey team performed the survey by its normal means, i.e. triangulation and distance measurements with

Wild T2
Wild DI 3
12 tripods with constrained centering,

altogether 234 brass-bolts, which have a good point definition. These 234 signalized points form, together with some original trigonometric points of higher order, the basis of the Vienna test. The adjustment of the frame network of 50 points resulted in R.M.S. position errors between ± 4 and ± 11 mm. From the twofold polar measurements of the other points a R.M.S. position error can be estimated in the order of ± 1 cm. Also, the heights were determined better than ± 1 cm. The town detail points are explained in Table IV-10.

From the control distances measured between the detail-points a R.M.S. position error of ± 23 mm has been estimated; but this MSE tells nothing about the identification difficulties concerning the very much different types of town details.

A second team of group surveyors, completely different from the first one, started also from the 234 brass bolts, for which the coordinates were known from the first team. Most of the points could be found again in spite of the already commenced underground construction activities in the test field area.

7. The Photogrammetric Measurements

In order to gain a number of measurements sufficiently representative for all questions, it has been decided to measure:

– each model six times (i.e. by six different centers), specifically three times with analogue instruments and three times with stereocomparators.
– the signalized points twice per model, the town details only once.

In the meantime the pilot centre received the results of all 156 models x). The 156

x) The last one was to be received in October 1977.

Table IV-9. The Photoflights for the Vienna Experiment.

The Flights (may 1973)				
Nr.	c	scale	illumination	
			sunny (.8)	diffuse (.9)
1.	30 cm	1:1 500	6 models	6 models
2.		1:2 500	4	4
3.		1:4 000	2	rejected
4.	21 cm		2	2

Table IV-10. The Town Detail Points of the Vienna Experiment.

Group Nr.	Typical town details	number of points
1	Corners of buildings and walls	303
2	House-connections on line	170
3	Doors and windows (Axes)	316
4	Pavements (straight lines and curves) x)	628
5	Rails (" " " ") x)	600
6	Fences	275
7	Masts, lanterns	139
8	Covers (of water- or gas-value casings), gullies	250
9	Trees, hydrants	137
x) Straight lines together: 223 Curved lines together: 93		Sum : 2.818

models can be computed from 7 strips with together 26 models, each measured 6 times. Altogether, I received about 180 000 measurements on punched cards and magnetic tapes. Previous to and after the measurements instrumental tests were to be executed following the recommendations of Working Group II/2 of the ISP. The reactions showed

- that there was not too much enthusiasm to test the instruments.
- that the time needed for the instrumental tests is not as dreadful as assumed in advance.
- that none of the 16 centres corrected the measured coordinates due to instrumental error, whereas some could have done so.

The rules for the measurements left the centers enough margin for the small variations to guarantee both representativeness for the practical case and excuses for the mere theorist. For example:

- The diameter of the measuring marks used varied from 10 µm to 60 µm.
- Some centers measured the two day-models in six parts and transformed the parts together by means of 9 or 11 ground control points, others used 20 good non control points for the marging, others measured the models in one package assuming that there were no changes in the measuring conditions of the instruments.
- Some centers compensated for radial distortion, some not at all.
- Some transformed the photo-coordinates to the fiducial marks in an affine mode due to the film shrinkage, some did nothing like that.

8. The Computations of Centers

The double measurements for the signalized points were meaned by the centers and the measuring accuracy was computed, eventually existing systematic effects had to be allowed for. The models were absolutely oriented by linear three dimensional similarity transformation using 9-11 ground control points well distributed over the entire model area. The R.M.S. was computed separately for the three coordinates.

Until now, I have only 60% of these computations and therefore should not report about it until all the models have been compared and checked.

9. The Computation and Analysis Program

The Experiment Vienna includes three groups of features:

- Points;
- Straight lines; and
- Curves.

For the points all computations will follow in principle the known line of the experiment Reichenbach. The confidence intervals will be added for a realistic interpretation of the results.

The straight line elements will be computed such that the lines fit best to their three defining points. The lines are then packed and cut near the ends of the first terrestrial measurements. The indefinite number of points within the normal length of the straight line have a certain mean linear deviation and a mean directional deviation and show certain mean systematics. The latter well be computed separately for lines parallel to sun illumination and orthogonal to it. But I don't think we can find out any systematic distortion.

The curves are treated similarly. The first terrestrial measurements form the basis for all comparisons. For each base-curve a trend circle can be computed. The deviations of the measurements from the trend circle are interpolated by a spline function in the form of a truncated power function. The spline functions can easily be compared with one another at any X of the trend-circle-length.

In the near future the results of the measurements will be read into our computer, checked, sorted and merged. All points will be checked earlier in order to further computation. And that is the current status of the project. The preliminary final report may be expected for the Hamburg ISP Congress.

Grün

Why did you use the very large image scale 1:1500? If we check the theoretical accuracy expectations of bundle adjustment in this case, we then find out that we may get a planimetric coordinate accuracy of 4.5 mm from photogrammetry. If further investigations are being thought then the terrestrial geodetic coordinates must match this accuracy level, or have to be better. That is not easy to get. Therefore, I think we should use for photogrammetric investigations a smaller image scale in order to avoid problems in the control point coordinates.

Waldhäusl

You cannot extrapolate from the normal range of aerial photogrammetric scales to these very large scales, for several reasons. First, the twin-engine aircrafts which must be used for safety reasons, in town areas, are too fast. We should use helicopters. Secondly, the lowest flying height permitted is 1 000 m over Vienna or 600 m over the small Austrian towns. Lower flights need special permits which we cannot hope to get. Speed and vibration cause errors that have not been included so far in normal photogrammetry. Thirdly, the details to be measured are much bigger than the measuring mark. In normal photogrammetry their sizes fit together. Again the conditions are altered.

That is why the extrapolation of the accuracies as it is experienced in normal aerial photogrammetry, is not reasonable. For sure there are other errors than just those determined by the extrapolation. The Commission C tries to find out how far the extrapolation may be used.

Dorrer

Completing the data processing phase will take at least a couple of years?

Waldhäusl

I think in 1 1/2 years we will have everything ready, although the Commission might discuss it longer.

Dorrer

Gentlemen, we have considerably overdrawn our allotted time. I think, however, the session was worthwhile. The diversity of the individual pilot projects, their wealth of information, and the methods being employed, have demonstrated clearly, the enormous complexity and problematics inherent in integrated surveying and mapping systems. Still, a large amount of both fundamental and applied research must be done within our profession.

I would like now to close this session.

SESSION V

COMBINATION OF PHOTOGRAMMETRY AND FIELD SURVEYS IN INTEGRATED SURVEY SYSTEMS

Moderator	E. Dorrer (Germany)
Panel	B. Dubuisson (France) W. Tegeler (Germany)
Discussants	A. Chrzanowski (Canada) K. Blachnitzky (Germany) O. Neisecke (Germany) R. Dörschel (Germany)

This session dealt with the following issues:

(1) What is the optimal combination of photogrammetric and ground surveys in the densification of control networks and in detail mapping for integrated systems in rural and urban areas?

(2) Is there a need for reviewing presently existing surveying standards and specifications in view of the combination of photogrammetric and ground surveys for computer assisted mapping?

S E S S I O N V

Dorrer

We heard yesterday in Session II about some accuracy statements. It has been a pretty well established fact that photogrammetry can compete, on a rather large number of occasions, with ground surveys. Whether this is economic or not has been touched upon a bit yesterday as well; but perhaps we can summarize and add to this today in session V. However, both methods should really not compete with each other; both methods of surveying, viz. aerial and terrestrial, should complement each other. The question no. 1 in this session V indicates this, and yesterday's discussion tended to indicate it, too. We should search or strive for an optimal combination of photogrammetric and terrestrial surveys. How far this combination should go in the densification of control nets or in detail mapping, perhaps we will be able to find out here.

Let me summarize briefly some thoughts in the following few minutes. We have got, on one hand, very homogeneous results from the photogrammetric surveys. On the other hand, from the ground surveys having been carried out some years ago, we have to expect a rather high degree of heterogeneity. We have seen, at least in some of the presented pictures, that it is still difficult to put the two different levels of homogeneity together. So, we have to think of some sort of integration of different methods, a coordination of surveys, a combination. It seems to me that the question of densification of, let's say, third and fourth order control, can be answered easily by photogrammetry. And even for relatively small areas this might be as economic or even more economic than by ground surveys. It is more difficult to answer the question how, or when the transition between photogrammetry and ground surveys should take place in detail mapping; perhaps we shall touch this in this session. Another problem is very much involved with monumentation and targeting. If we combine both methods of surveys we have to take into account all the possible costs. Monumentation in this way is a very costly procedure.

I would like to ask first Professor Dubuisson to give this comments on question no. 1: "What is the optimal combination of photogrammetric and ground surveys in densification surveys and in detail mapping?"

Dubuisson

I want to make a preliminary remark about accuracy. Your general conclusions result from a syllogism for which the premise is not conformable to my opinion. You are speaking about cadastral work because it needs the highest accuracy as compared to the other integrated surveying systems.

Nevertheless, experience shows that various information systems need only very poor accuracy, but require great speed for their realization, for reasons of political or economical obligations. So, you may initially have a low accuracy, and you can later substitute a new and correct geometrical base, i.e. when new accurate maps will be established, without disturbing the structure of the collected files of information.

The fundamental subject is the structure of the various information files related to the geometrical base as the common reference. In this way, correlations between the various data banks are easy.

Speaking about the optimum combination of photogrammetric and ground surveys in the densification of control networks and in detail surveys for integrated mapping systems concerning rural and urban territories, we have to consider the following:

(1) Fundamental, experimentally recognized principles
   - define their "integrated data" on the geometrical level,
   - deduce their "fineness", i.e. the accuracy of the geometric support medium for these data.

(2) Working principle: The visibility of objects classified on the pictures in itself defines limits for the use of photogrammetry. For example:
   - areas hidden by perspectives of buildings or superstructures,
   - virtual nature of legal boundaries of rights and properties

(3) The extreme variety of integrated data on the plot leads to infinitely varied solutions. Examples:
   - Periodic checking of crops on "extensive" rural parcelling may be handled solely by photogrammetry and remote sensing on geometric bases collected in-flight by a radio positioning system, and without any ground operations.
   - The rural parcelling plan lies in the realm of traditional numerical photogrammetry, for it concerns only taxation and cultivation, like accurate rural cadastres with pre-indicated fixed boundaries.
   - Urban development plans usually contain only visual data. Whatever their scale, they belong to the photogrammetric field, par excellence.
   - Urban plans intended for reparcellation of old neighborhoods are usually at scales 1:500, and are compiled by photogrammetry with an important amount of complementary data collected by completion on the ground.
   - The rigorous cadastral plan in cities may be established according to the mixed principles of certain "Länder" in the Federal Republic of Germany, or entirely on the ground, which is usual in the French cadastre; but, personally, I greatly prefer the former solution, especially since the development of analytical stereoplotters. On the other hand, the survey of underground utility networks (sewer, water, electricity, telephone, etc.), which is practical in the case of "new towns", is typically linked to ground operations serving as a basis for these integrated systems.

(4) The fundamental problem of integrated systems, however, remains one of reliability, i.e. updating
   - the geometric medium or photo-topographic plan
   - and associated data.

(5) In conclusion, a too ambitious program either in the generalization of uses, or in the quantity of details being considered, or in the accuracy is certain to fail. There are numerous examples of such failures. On the other hand, it would be of interest to create specific integrated programs which might be brought in later and rendered homogeneous via a computer file.

Dorrer

Could you give an example of a "too ambitious" program?

Dubuisson

I cannot give a name, but everyone knows the problem of ambitious programs. I do not want to remind you of the relative interdependence between data quantities and the scale of the map. But the question is the number of details included in the files, according to their nature, and the frequency of their utilization. We cannot store information in a memory which will be used in 40 years. We have to make use of the memory only of the current work.

Difficulties arise with the choice of memorized inquiries, specifically due to updating possibilities.

To avoid the various national files becoming disordered, we have in France a national commission of GEOMATIQUE which assures coordination between 40 services engaged in specialized data banks. This commission tires to find the common denominator for the needs, and to assure connections between data files. You think that is not so easy. However, common geographical coordinate references is the main way.

Four years ago, we had an example of national cooperation to establish the data file names "Répertoire géographique urbain" (R.G.U.), i.e. urban geographic data base, which was a new base for the census of population. Its purpose was to estimate all activities and motions of various parts of the population for each town.

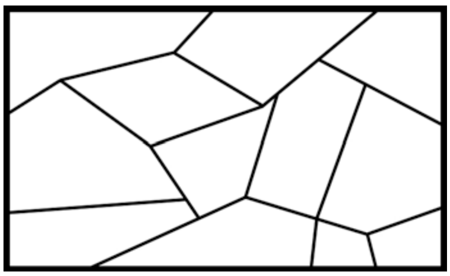


Figure V-1. All portions of streets between crossings are administratively coded.

The work was based on a schematically coded grid of streets (see Figure V-1), established at scale 1:2000, referred to Lambert coordinates on orthophotoplans at scale 1:5000 (aerial photographs at scale 1:20 000). It is not a regular map, but only a schematic geographic localization. The accuracy lies between 5 and 6 m. All important French towns (about 250) are included in the data files, now finished after three years, and ready for the users: 12 000 sheets of grid at scale 1:2000. I would like to draw your attention to the fact that only a very sparse amount of details is included.

On the other hand, we have undertaken in France two other kinds of numerical maps, mostly developed for details for cadastral and urban purposes.

Dorrer

Thank you very much, Professor Dubuisson. I would now like to ask Dr. Tegeler to give his contribution to the first question.

Tegeler

The optimal combination of photogrammetry and terrestrial surveys is a problem of accuracy, reliability and economy. To demonstrate this, I would like to give the following example: In 1974 the State Survey Office of Niedersachsen in West Germany carried out photogrammetric network densification in the rural area of Hordorf, east of the city of Braunschweig (see Fig. V-2 and Table V-1).

The photogrammetric adjustment was performed by the extended computer program "Bundle Adjustment with Additional Parameters (BAP)" by Dr. J. Müller, Hannover.

In Niedersachsen the densification of the 2nd order control network is carried out by precise traverse measurements (relative accuracy 1:200 000). We usually obtain in this densification step all 3rd order control points and nearly half of the 4th order control points. In Version II the control points determined in this way are used.

The main difference between a coordinate based cadastral system and a system based on field documents is that in the coordinate based system the original measurement on boundaries are thrown away. For reconstruction purposes the necessary measurements are derived from the coordinates. The problem is to maintain the required accuracy in a coordinate based cadastral system.

The obtained accuracy of ± 2 cm corresponds to the requirements of a modern network, but the improvement corresponding to the perimeter control is not satisfactory.

The accuracy could be improved by enlarging the photo scale, but in this case the costs would reach those of the terrestrial determination.

Costs of photogrammetric network densification in rural areas, as derived from the test area of Horsdorf (54 km^2), subblock with 675 new points, are as follows:

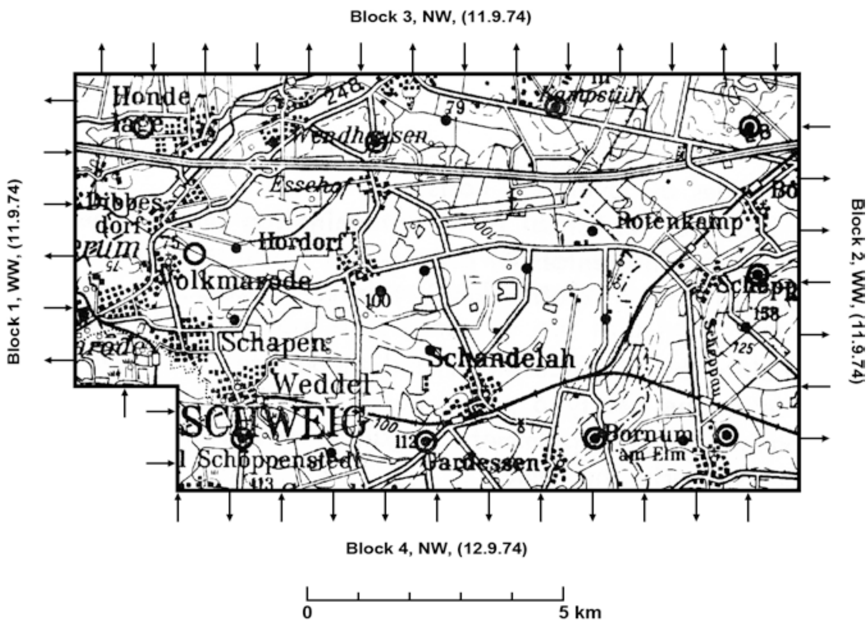
(1) Planning, terrestrial surveys	DM	4 500
(2) Photo flight (scale 1:6000, sidelap 60%)	DM	6 500
(3) Signalization (minor control points; center an 2 auxiliary points each; DM 26 per point)	DM	18 300
(4) Selection of tie points, measurement of photo coordinates (256 models x 0.9 hours per models x DM 57 per hour)	DM	16 500
(5) Computations (BAP)	DM	4 500
TOTAL:	DM	50 300

That means DM 75 per point. The two auxiliary points for each minor control point were chosen in order to increase the reliability of the measurements.

The costs decrease in the case where the boundary points, building corners, etc., are determined simultaneously with the aerial triangulation.

Chrzanowski

I'm sorry to interrupt you, but could I ask a question? – This price, would it be the price if you do it for a client, i.e. including all the overhead costs, such



Enlargement of a section of the scale map series TÜK 200, sheet no. CC 3926 Braunschweig, 1972 edition; printed by Institut für Angewandte Geodäsie, Frankfurt; reproduced with the permission of Niedersächsisches Landesverwaltungs-amt, Landesvermessung, from November 24, 1976, B5-251/76

Block size: *6 km (NS) x 12 km (EW)*
Photo scale *1:6000*
Photo flight *EW: WILD RC 10, 15/23, sidelap 60%*
NS: Zeiss RMK A 30/23, sidelap 60%
Number of control points and check points: *44*
Terrestrial accuracy in planimetry: $m_{EN} \approx 1$ *cm*

Figure V-2. Test area of HORDORF: Arrangement of the Strips in the four single Blocks, and Distribution of the Horizontal Control Points (HCP) (Version I, 10 HCP: big circles; Version II, 21 HCP: small circles, filled).

Table V-1. Planimetric Accuracies (RMS errors):

	HCP-Version I: 10 HCP at the Perimeter ($i \approx 6b$)	*HCP-Version II: 21 HCP distributed all over the 54 km^2 – Subblock ($i \approx 3$-$4b$)*
Single Blocks	*4.4 cm (7.3 μm)*	*3.7 cm (6.2 μm)*
Double Blocks $q = 60\%$	*3.2 cm (5.3 μm)*	*1.9 cm (3.2 μm)*

(Maximum errors ≈ 3x RMS errors)

as productions costs? Or is it the price you pay if you would just do it for yourself?

Tegeler

Yes, it includes all overhead costs.
The corresponding costs for terrestrial point-determination (measurement and adjustment; however, without monumentation) are:

a) Points in precise traverses (2 points/km^2); relative accuracy 1:200 000) DM 160,–/point
b) Minor control points (by distance meter and theodolite) DM 115,–/point.

As to a) we can determine nearly 6 points per day and as to b) nearly 12 points. Finally, the comparison of photogrammetric against terrestrial determination shows that the spent time is nearly the same.

Dorrer

The floor is now open for discussion.

Chrzanowski

I would like to comment on the costs of the terrestrial densification surveys. We have performed several cost analyses for the terrestrial densification surveys, and we came up with an average price of 60 dollars per point in urban areas where we have points every 200 m with a relative positional accuracy of 2 cm at the 95% probability level. So, it is quite comparable to the figure you came up with, because 60 dollars is about DM 140 per point, but with a higher accuracy because we achieved relative accuracies of 2 cm at the 95% probability level.

Blachnitzky

In Bavaria a trigonometric point costs more than 1000 Marks. For 160 DM you cannot get it monumented.

Tegeler

It was only the cost of measurement and adjustment (without monumentation) for determining points in precise traverses (2 points/km^2).

Blachnitzky

I cannot believe it. We need 1000, perhaps 800 DM without monumentation; and Mr. Spindler said something about 5000 DM.

Tegeler

Does it include the erection of observation pillars?

Blachnitzky

Oh, no!

Dorrer

I think that despite the questionable figures we've heard so far, they nonetheless offer the possibility for a relative comparison between the two methods used in Hannover. Although the speed is obviously the same for the two methods, what surprises me, the costs are approximately cut into half when using photogrammetry.

Dubuisson

Do you think it is very difficult to work in the various towns, when you have problems with the roofs, with the over-hanging, the problem of the traffic, and so on, where you cannot make very many details? Because I think most of the difficulties are there on the ground, not in photogrammetry.

Tegeler

There are some more difficulties in urban areas.

Blachnitzky

So, a cadastral control point costs about 200 DM with monumentation?

Tegeler

Not for boundary points, but we agree with that for network densification points.

Neisecke (Translated from German)

To the costs of monumentation I can say the following: We need half a day per point in the open field, i.e. a survey crew consisting of 2 helpers and one leader. This costs some 280-300 DM for the monumentation of a trigonometric point.

Chrzanowski

In our Canadian test the monumentation costs only 40 dollars per point. But we use the wall monumentation, as I said before.

Dorrer

We are very short of time, and still have two more presentations in this session. One is by Dr. Neisecke, who is the head of the cadastral office in Wolfenbüttel, Niedersachsen in Northern Germany; the other is by Mr. Dörschel, who is with the Bavarian Landesvermessungsamt in Munich. I would propose to immediately proceed to these presentations.

Neisecke

INTEGRATION OF TERRESTRIAL AND PHOTOGRAMMETRIC SURVEYS
(Translated from German)

Introduction

It is the purpose of the author's photogrammetric studies to produce basic field maps of settled areas at the scale 1:1000. Up to now only "insular" maps have been available with most varying scales ranging from 1:150 to 1:2133 and 1:3000, dating back to ancient mapping activities in the period between 1746 and 1784. The following brief report shall outline how, in the course of these endeavours, a symbiosis can be found between the available terrestrial material, the photogrammetric aerial photographs and analysis, and the complementary terrestrial studies, and how all these studies effect one another in an integral way.

The aim of the 1977 aerial surveys in the author's official region was to produce basic field maps in 1:1000, and to gradually cover the settlements of the region /1/, /2/. The prevailing partial map in the Gauss-Krüger coordinate system 1:1000 of the localities of Cramme und Börßum gave rise to completing the basic field mapping works in these areas, the more so as an application for the production of mapping bases for construction plans in 1:1000 finally initiated the photogrammetric flight.

Methodical Procedure

The procedure of this year's photo flight has been conceived in accordance with many years of the author's experience, particularly according to the principles demonstrated in /1/ and /2/.

Modifications of the basic concepts given in /1/ and /2/ were necessary for the three sections Cramme, Börßum and Bornum, according to the local peculiarities. Principally, the image scale 1:3300 counts as nominal scale in connection with an RMK 30/23. Forward overlap is chosen as 80% in order to achieve selection of those stereo pairs best situated to the map margins. Low flying speeds must be flown in order to avoid extensive blurring of the imaged signals in flight direction. At a flying speed of 120 km per h and an exposure time of 1/250 s, the displacement d amounts to 0.13 m on the ground. A signal of the size 10 cm x 10 cm appearing 0.03 mm x 0.03 mm in the scale 1:3300 would yield a deformation of the signal to 0.04 mm, in case the total image displacement would actinically effect the film. However, only 75% of the signal movement is imaged effectively, thus deforming the quadratic format of the original signal to some rectangular or elliptical form of the size 0.03 x 0.06 mm.

For the area Cramme an image scale of 1:1700 was chosen for reasons to be explained later. Due to the limited exposure interval, only a 60% forward overlap could be flown. In this scale the signal would be imaged in the size 0.06 mm x 0.06 mm. The flying height being only half as large, the exposure time could have been reduced to 1/500 s, thus reducing the effect of image blur to also 0.03 mm. Image blur would thus hardly be visible, for the signal size would only be enlarged to 0.06 mm x 0.09 mm.

Agfa-Color aerial film was used for this year's photo flight. As a consequence, besides the white signals which were either painted with white street marker paint or layed out as plastic discs, either targets were painted red with luminescence paint, or colored signal plates were layed out or glued on. Additionally, yellow adhesive stripes were used. Corresponding experience shall be reported upon at a later date.

The procedure was coordinated with and adapted to the given map base. For the Western joining region in Börßum, basic maps, fixed on Pokalon film, exist at the scale 1:1000. Consequently, the map manuscript of all unobjectable surveys connected to the net is prepared for automation, and will later be plotted on Pokalon (Figure V-3; continuous lines). Survey lines not yet included in the survey line network are prepared for automation by signalizing their end points (dotted lines and circles). The coordinates of these points are then determined during the measurement on a stereocomparator PSK-2 together with the remaining signalized traverse stations and control points (black triangles) or model transfer points.

Signalization of all traverse stations was not generally required here, however, the accuracy of the coordinate determination was to be compared between the old terrestrial net, the old terrestrial net with new network connections, and the homogeneous photogrammetric net.

It must also be mentioned that since 1973 almost all the author's survey area has gradually been covered by a new electronically measured 2nd, 3rd and 4th order network, in order to eliminate the known network discrepancies of the "Reichsamt für Landesaufnahme" net, particularly within the 2nd order networks /3/.

For the Börßum area, the net configuration of the old traverse network (Figure V-4; thin lines), the trigonometrically renewed 3rd and 4th order network (dotted/hatched lines), and the new network tie between trigonometric and traverse network, carried out by overlapping skeleton traverses (thick lines), can be seen in Figure V-4. Preliminary computations yielded a net accuracy of 3-4 cm for the skeleton traverse net, an accuracy that is only slightly inferior to the accuracy of 1-2 cm of the trigonometric network. Detailed results cannot be published at this time.

The same conditions as in the Börßum area can be applied to the new network tie in the Bornum area. The scale of the "insular" maps in Börßum is 1:1500, while in Cramme and Bornum up to now completely obsolete "insular" maps at 1:3000 have existed, the origin of which can be traced back to the former Brunswickan "Landesaufnahme" between 1746 and 1784 /4/.

In Cramme, partial plots in 1:1000 of the newer continuation surveys were already available on aluminium plates. They were continued and completed in as far as the connection to the given traverse and line network permitted. All survey line end points not tied in were signalized. Their coordinates will be determined within the photogrammetric restitution phase (Figure V-5; circular rings). Based on these lines, the measurement field can subsequently be plotted on aluminium plates. thus, terrestrial measurements and the photogrammetric determination of fixed points complement each other in an integral way. Moreover, the integration of terrestrial and photogrammetric surveys comprises both the survey of buildings and the plotting of the graphical boundaries.

Besides the measurements of the roof eaves by means of a roof plumb prism, the centric and eccentric signalization of the corners of buildings was examined. The signalization was verified to scale in the survey drawings (Figure V-6). In addition to these tieing measurements, the lengths of buildings are to be determined

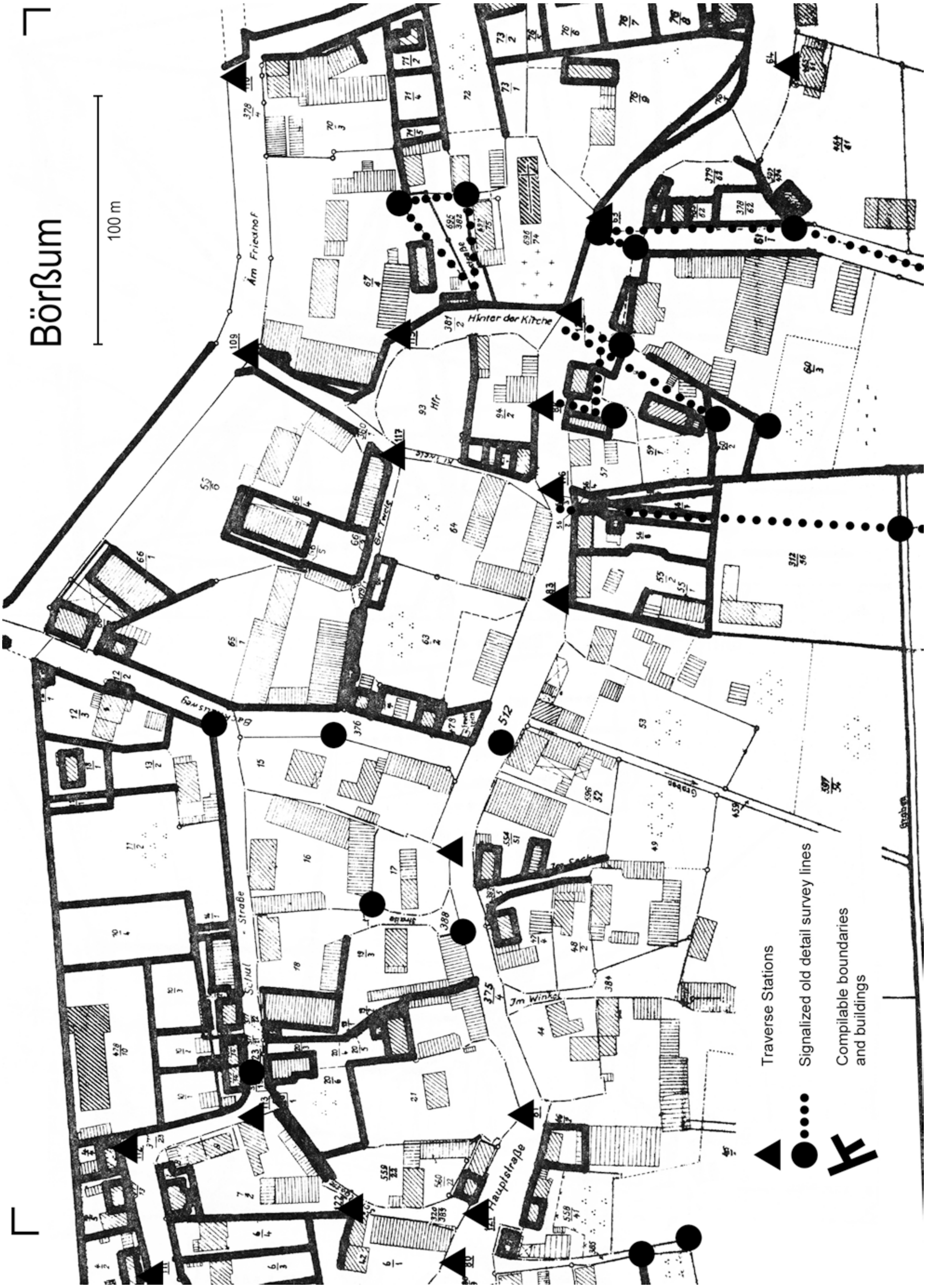


Figure V-3. Prepared Map Manuscript, Börßum area.

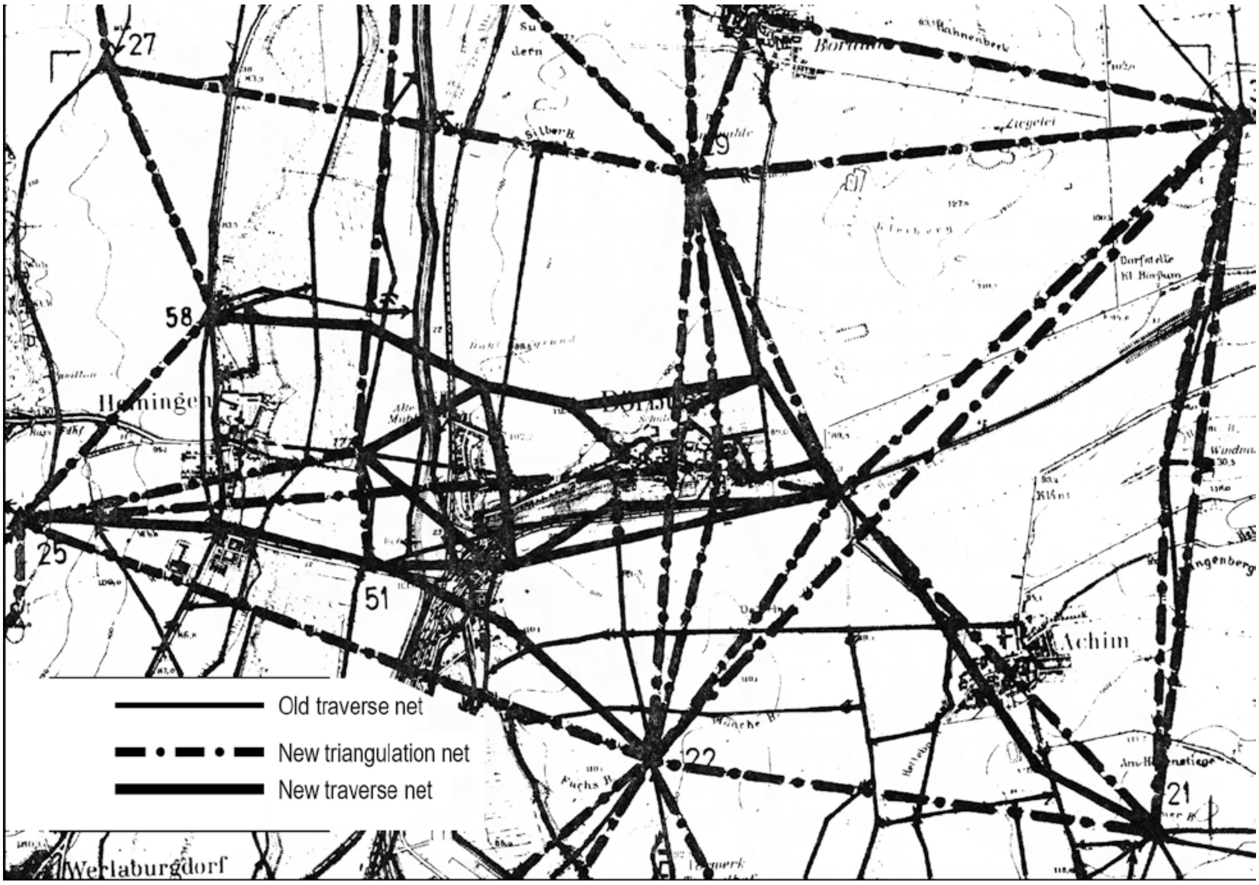


Figure V-4. Control Networks in Börßum area.

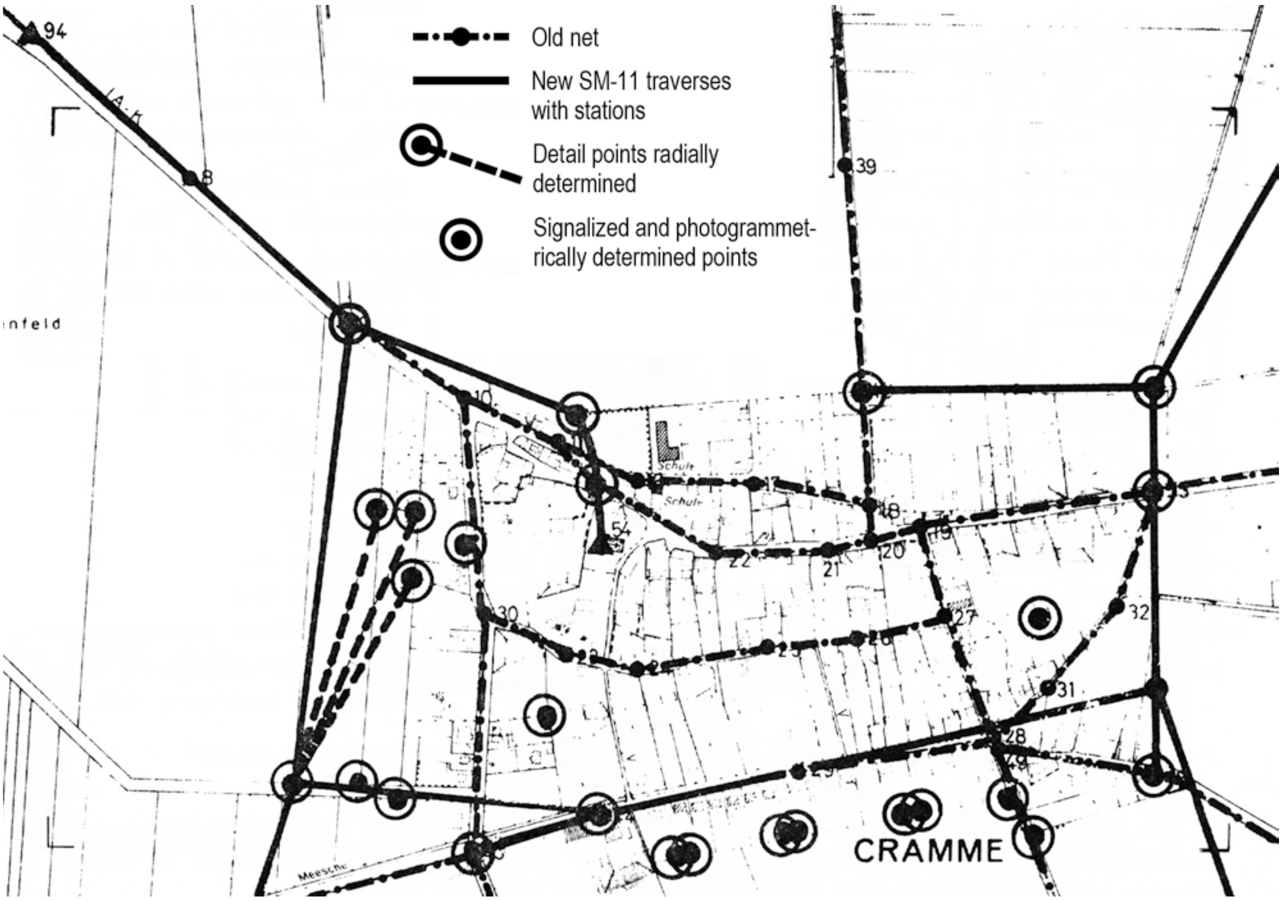


Figure V-5. Control Networks in Cramme area.

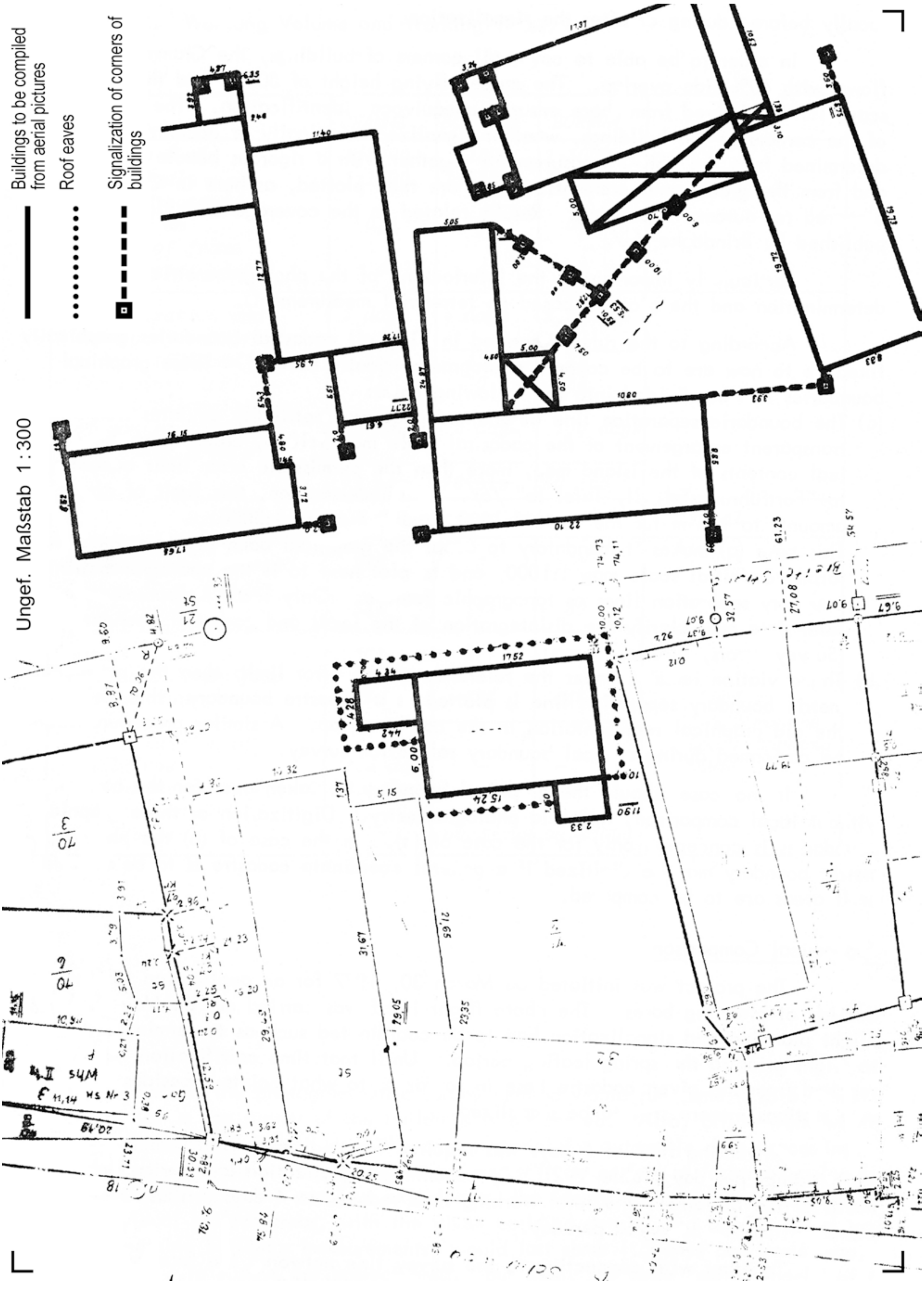


Figure V-6. Preparation for Photogrammetric Measurement.

locally before, during or after the signalization.

In order to be able to cover all corners of buildings, the Cramme area was flown with 60% side overlap. The chosen flying height of 500 m and the photo scale 1:1700 derived from there ensured unequivocal identification. The coordinates of the corners of the buildings, whether signalized centrically or eccentrically, are determined from the PSK-2 measurements together with a rigorous bundle adjustment, and from the ground measurements. They are then plotted, as here in Cramme, or prepared for automatic plotting. Results related to the coverage of buildings are published by Brindöpke /5/.

Particularly important is the interlocking of the photogrammetric coordinate determination and the plotting based on terrestrial measurements.

According to the rules described in /1/, all cadastral boundaries graphically fixed up to now are to be covered photogrammetrically as well. These graphical boundaries can be divided into the following cases:

(a) The boundary separation line determined photogrammetrically deviates from the transparent enlargement of the cadastral scale map 1:1000, based upon the graphical contents of the island map, <u>more</u> than the permissible error limit according to "FortführungErl. II, Tafel Ib" /6/. In Niedersachsen, this limit of error amounts to 1.3 m for the scale 1:1500, and 1.7 m for 1:3000.
This case (a) makes it mandatory to adopt the graphical boundary from the enlarged cadastral scale map 1:1000, and to plot next to it the photogrammetric boundary separation lines as topographic feature. Only local measurements at a later date may clarify the disintegration of the local and cadastral boundary (Survey errors, plotting errors).

(b) The deviation remains under the tolerance of the error limit; then the photogrammetric boundary separation line is plotted as a cadastre boundary, thus deleting the old graphical representation in the cadastre map. A similar procedure would be performed during a local boundary relocation survey.

In no case should the graphical boundary be taken over for the basic map without local comparison, here via photogrammetry. Digitization of these graphical boundaries is concerned only for the case of (a). In the case of (b) the photogrammetric boundary may be digitized if a general coordinate cadastre is to be established, or if areas are to be computed.

<u>Economical Comparison</u>

The project was initiated on March 30, 1977 for an application for the production of planning bases. The photo flight itself was carried out on May 3, 1977. Flight planning and signalization had to be coordinated such as to terminate the photo flight prior to the spring leafing period. Until that time clarification had to be reached from the given cadastre base in so far as to what points – besides the traverse stations – were still to be signalized.

A working time of 5 days was required for the survey of 152 buildings, i.e. 30 buildings per day (Table V-2). By combining signalization and perimeter measurements of the buildings, the total working time reduces to 4 days. Thus, some 40 buildings may be surveyed per day.

Together with connecting to the survey line network, the terrestrial orthogonal detail survey method achieves only some 7 to 8 buildings per day.

Table V-2. Working Volume and Working Times.

	CRAMME	BÖRSSUM	BORNUM	
Old map scale *Photo scale* *Size of covered area in km^2* *Number of frame scale maps: 1:1000*	*1:3000* *1:1700* *0.4* *4*	*1:1500* *1:3300* *0.4* *4*	*1:3000* *1:3300* *0.4* *4*	
Signalization and survey of traverse points (PP) and fix points (FP) *Height determination of control points and check points*	*5 days* ——— *30* *17* *1 day* ——— *78 pts*	*5 days* ——— *42* *16* *2 days* ——— *76 pts*	*2.5 days* ——— *22* *23* *1.5 day* ——— *60 pts*	
Buildings within the project area				*Total*
Unobjectably surveyed *Taken from aerial photography*	*249* *152*	*87* *139*	*102* *80*	*438* *421*
Total *Per cent taken from aerial photographs*	*401* *38%*	*277* *68%*	*182* *44%*	*50% = 4 1/2 months local working time*
Signalization of buildings *Perimeter measurements* *Identification of buildings*	*2.5 days* *2.5 days* *–*	*–* *–* *ca. 3 days*	*–* *–* *ca. 2 days*	

Hence, the photogrammetric survey method would run some 4 to 5 times faster as far as the survey of the buildings is concerned. Also, office work would be simpler for the preparation of the data material for automatic data processing. However, the identification of roof eaves can still be performed faster on a local basis. According to my previous experience, the identification of the buildings for the individual project areas, with the given building density and a 50% deficiency of unobjectable buildings measurements, would last some 1.5 days per frame map, hence some 2 to 3 days per project area. But then, the later "setting-back" of the buildings would be more labour-intensive, and would contain a certain amount of uncertainties, unless a recent proposal by Brindöpke would be considered which yields coordinates of the corners of the buildings.

The integration of terrestrial measurements and the point measurements on a stereo comparator is one phase. In the following, some thoughts are given on the economy of the second photogrammetric phase, i.e. the analog stereo compilation from the same imagery.

At this time, the original terrestrial base data, and the (terrestrial) data of the signalized end points of the detail survey lines have been represented in the maps to be produced. The buildings were compiled either in the process of the manual plot on aluminium film (Cramme), or by a computer compatible listing and plot on transparent film. What follows is the analog stereo compilation of other topographic features, e.g. street lines, hedges, walls, fences, together with the partial graphical boundaries. These topographic delimitations extending less straightly can be generated from the analog compilation much better and more accurately than from a conventional terrestrial measurement with the determination of individual points.

Whether such a line traverse has to be dissolved into individual points during a compilation of areas or a determination of coordinates, will result from the local situation. Already today there are available suitable digitizers easily manipulated for that purpose.

In any case, the survey of such line traverses can be performed much, much faster photogrammetrically than from equivalent terrestrial measurements. Altogether, herein lies the main advantages of the photogrammetric compilation.

A numerical figure may illustrate this. The entire photogrammetric analog compilation of the 6 basic scale maps of Remlingen lasted 6 days, or one day per basic map (/2/, p. 355). Within the given project areas 12 basic boundary maps could be produced within a year. Only 14 days of field work were required in Remlingen, up to now 19 fieldwork days have been performed, and another 10 days estimated for identification, measurement of roof eaves and supplementary measurements. This is a period of time superior to any terrestrial working time. Surveying the missing inventory of buildings alone would have required locally between 60 and 70 working days for these three projects, without the supplementary measurements in the network for the purpose of connecting the detail survey lines not included yet, and without the survey of other topography. Nor further comments are required for the compilation accuracy from the photo scale 1:3300, for the errors are in the range of 3 to 4 cm. For the project Atzum (/2/, p. 356) the RMS coordinate error amounted to 3.3 cm. In the case of Atzum /2/ the eccentric targeting of 4 cm for a control point already disturbingly affected the error distribution in such a way that this point had to be removed from the adjustment; the error value of 6 cm for this point was later explained mainly by its eccentric signalization. The photogrammetric compilation accuracy might be kept in the order of the control point accuracy of 1 to 2 cm in case a photo scale of 1:1700 is chosen.

Conclusion

The practicality of using the terrestrial measurement data material as much as possible has been demonstrated here. As far as these measurements are not yet connected to a supporting traverse of fix point field, signalization and subsequent coordination of the detail survey line points via comparator measurements is an unconditional necessity in order to economically include also this terrestrial data material for map production.

According to the state of the mapping base and to the general use of EDP, the terrestrial records may, for example, be established beforehand either manually or for preparation to EDP, and automatically plotted on Pokalon film.

As a result, in order to be able to work economically, the old and original terrestrial measurements, the new networks, photogrammetric flights and comparator measurements, together with compilation of further older or newer ground measurements, as well as compilation of the topography by analog means, and subsequent local supplementary work, can and must, be integrally and mutually connected.

It was shown as to economy that the inventory of buildings can be performed 4 to 5 times faster with photogrammetry than by ground surveying.

The advantage of the currently feasible photogrammetric production of cadastre maps lies in the

a) gaining of a homogeneous point field within the control point frame by means of the bundle method with additional parameters /10/, without essential tensions in the model transfer,
b) point measurements of the corners of buildings with a rather accurate determination for coordinates, and
c) linear analog compilation of all topographic features within cartographic accuracy of 0.15 mm (/9/, p. 35).

With that, almost all requirements are met which had been posed to photogrammetry in previous years. The integrated processing of terrestrial and photogrammetric measurements, particularly in view of better identification from colour photography and of enlarging the photo scale up to 1:1700 or 1:2000, has crystallized in a very economic method for producing boundary base maps for establishing a coordinate cadastre.

The author. therefore, proposes to continue conducting research along these lines in order to publicize this method on a larger scale, and to recommend its use as the most economical method for the production of boundary base maps.

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Dörschel

THE ECONOMICAL SURVEYING OF SUBURBAN AREAS BY A COMBINATION OF TERRESTRIAL AND PHOTOGRAMMETRIC WORKS
(Translated from German)

It is not my intention to deliver a systematic lecture, but I rather would touch only individual subjects or points that appear to me particularly important in view of my chosen title.

Table V-3 "Prerequisites – Aims" shows the wealth of possibilities we may be confronted with in our work.

Figure V-7 showing the "Flow of Work" roughly outlines how the individual tasks are interrelated, how one step depends on the other, and which phases can proceed simultaneously. These interrelations are to be continually kept in mind.

A last preliminary remark: in this paper I am always thinking of suburban and urban areas, i.e. regions where most of our projects occur.

<u>Point no. 1:</u> "The production of new maps almost always requires photo flights for the acquisition of topographic features. Let us utilize them for the determination of points!"

The developed housing areas of our cities are favorable for terrestrial point determination. A systematic structure of a network is difficult to accomplish, the field work is hampered and endangered by traffic, instruments are threatened by theft and damage. The photogrammetric determination of points requires targeting; the targets can be durably painted on paved streets during the period of point search, thus keeping the points visible from the air for weeks. If the control net, the flight planning and the compilation are properly layed out and conscientiously carried out, R.M.S. coordinate errors of 5 μm may safely be achieved, i.e. 2 cm from 1:4000 photo scale. With such an accuracy, a point field may not only be constructed over large areas satisfying all modern requirements, but also closely neighboring points may be fixed with the necessary accuracy.

If there are larger areas between the developed housing area and the control point field, and if in these areas the points are to be determined by ground surveys, then the control point field may either be advanced during these measurements, or a very loose densification can be performed photogrammetrically with spacings from 200 to 300 m. Its points may then be used as reference points for the ground surveys at a later date. Hence, with aerial photography of a larger area, the point determination may be quite restricted to a subarea.

<u>Point no. 2:</u> "For special cases separate photo flights should be scheduled."

Example 1: In our latitudes, over-grown water courses may best be photographed and compiled shortly after the snow melts.

Example 2: Very densely frequented main streets may well be photographed in the early morning hours of high summer, i.e. when the traffic is not awaken yet, but sufficient brightness exists.

Example 3: During the early morning hours of high summer, very narrow city areas may be photographed. The very long shadows are then sufficiently brightened. High lateral overlap and long focus cameras diminish largely the endangering of obscured details.

Table V-3. Prerequisites and Aims.

PREREQUISITES

1. WITHIN THE FIX POINT FIELD MAY BE GIVEN

   1.1 A DENSE FIX POINT FIELD OF HIGH ACCURACY
   OR

   1.2 A FRAGMENTARY FIX POINT FIELD OF INSUFFICIENT ACCURACY, WHICH IS TO BE KEPT FIXED OR TO BE IMPROVED.

2. FOR THE FIXING OF BOUNDARIES MAY BE GIVEN

   2.1 A COMPLETELY COORDINATED POINT FIELD OF HIGH OR LESSER ACCURACY
   OR

   2.2 A SPACE COVERING FIELD OF LOCAL NUMERICAL SURVEYS
   OR

   2.3 A GRAPHICAL FIXING OF ALL BOUNDARIES (WITH A NUMERICAL SURVEY OF SEVERAL BOUNDARIES
   OR

   2.4 NO SURVEY AT ALL.

3. for topographic features may be given

   3.1 A SURVEY OF ALL FEATURES MAY BE PLOTTED
   OR

   3.2 A SPECIAL SURVEY OF SPECIFIED FEATURES
   OR

   3.3 NO TOPOGRAPHIC SURVEY AT ALL.

AIMS

1. WITHIN THE POINT FIELD
2. CONCERNING THE OTHER CONTENTS OF BOUNDARY MAPS
3. CONCERNING UPDATING

OUR AIMS ARE DIRECTED TOWARDS

1.1 A COMPLETE COORDINATE CADASTRE
OR

1.2 A GRADUALLY FORMING COORDINATE CADASTRE
OR

1.3 A COORDINATED FIX POINT FIELD

2.1 A COMPLETELY DIGITIZED BOUNDARY MAP
OR

2.2 A PARTIALLY DIGITIZED BOUNDARY MAP
OR

2.3 A GRAPHICAL BOUNDARY MAP.

3.1 A REVISION IN CASE OF NECESSITY
OR

3.2 A PERIODIC REVISION
OR

3.3 A SPORADIC REVISION.

Example 4: Surveying the progress of a large construction site is best achieved photogrammetrically by means of a fixed, continually revised control point field.

Point no. 3: "Numerical compilation and computation should not impose restrictive conditions!"

The photographs should contain well measurable fiducial marks (possibly 8) in order that subsequent compilation can be integrated in the primary compilation without loss of accuracy. The measurements on the comparator should proceed evenly and smoothly for the sake of obtaining quick results without having to think of how many pictures are to be measured. The bundle adjustment should be theoretically rigorous, flexible with respect to unconventional arrangements of the photographs, and easy to use for the detection of errors.

Point no. 4: "The newly determined point field is to be secured sufficiently, possibly also on up-rising masonry!"

Today, conventional monumentation with or without subground securing, does not suffice any more. Survey sketches in the old manner are only conditionally useful. It is better, in addition to the points having to be determined for setting up a cadastral fix point network, to determine the coordinates of further points photogrammetrically or terrestrially such that, instead of just one point, a whole point nest is available. These points may be determined by orthogonal or polar ground survey methods, in the latter case advantageously by means of self-recording tacheometers. One should always try to determine points on vertical surfaces which are less endangered by road construction. Here, monumentation may be achieved by using adhesive or shot marks. It is suggested that the use of adequate enlargements of aerial photographs be tested as the basis for survey sketches.

Point no. 5: "The old survey records which are always available here in developed housing areas should be utilized as extensively as possible for the determination of boundary points, and not only for their detection and relocation. For that purpose, though, separate computational procedures are required!"

With new measurements carried out simultaneously, one can determine boundary points without redundancy, and check the coordinates by adequately selected distances ("Spannmaße"). However, if old measurements are to be used for the coordinate determination, one has to consider the risk that identical points shown in different records will not always be identical to the desired accuracy of 2-3 cm. However, the same points are referenced to in different records, and redundant measurements for these points are found in the individual records such that many redundant measurements almost always are given. Therefore, the point coordinates to be computed may be determined by means of an adjustment which reveals identity and measurement errors by correspondingly large residuals. Cooperating with university institutes, we are anxious to develop such computer programs. Incidentally, such old measurements can only be dealt with if they were not adjusted or otherwise altered.

In cases where the coordinates of points already exist for larger areas, and the point field is to be transformed by keeping fixed relatively many identical points, "conventional" transformation procedures such as similarity ("Helmert") or affine transformations are only conditionally usable. What is required are separate space-variant and "point-specific" transformation methods, some of which have been efficiently programmed in our office.

Point no. 6: "For all other compilations, the possibilities of photogrammetry should be tested and adequately utilized!"

Compilation of buildings: The purely graphical compilation with stereoplotters as well as the succeeding mapping by considering the roof corners and the perimeter of the buildings suffice for the production of the scale map 1:1000.

A higher accuracy – better than 10 cm – coupled with the possibility of automatic mapping can be achieved by digitization of the roof corners and by the succeeding automatic processing. Provisional computations have been carried out successfully in our office. An exact determination of the coordinates of the house corners is achieved by a survey of the building referenced to the photogrammetrically determined points; at the same time the point field will be resecured at the house corners. Here, automatic mapping is as equally possible as the computational determination of eventual built-overs. The photogrammetric graphical compilation of the buildings checks the terrestrial measurements.

Bridges: Besides the photogrammetric compilation, bridges still require terrestrial measurements for their proper mapping. It is advisable to target individual points on the edge of the bridge. In future, as far as possible, all other topographic features should be extracted from orthophotos. Whether they are to be acquired purely graphically or digitally is another question.

Concerning digitization of the contents of boundary maps, I shall mention only the following: presently our office uses automatic mapping procedures for boundary points, boundary distances, and buildings. Further digitization is likely to be considered only when the possibility exists for representing the contents of the digitization on a graphical display where corrections and revisions can be manipulated.

Point no. 7: "The Flow of Work" (Fig. V-7)

Let me, finally, once more discuss the flow of work. For our projects photogrammetry can provide decisive aids. Of course, the operators must be trained to be able to think systematically along the lines of all working phases. The main object, however, should be the integration of the photogrammetric part in the total project. The instant of time for the main photo flight should be between middle of March and middle of May, i.e., in average, end to April. In order to arrive at a reasonable flow of work, it should be possible to eliminate unavoidable errors and gaps in the field work already done during the same year, thus reserving the winter time for indoor work. The first computations must be completed by the beginning of September; hence, the results of the bundle adjustment should be available at the latest by the beginning of August. This also means that, at least for an essential part of the entire project, compilation of the photography and computation of the bundle adjustment must be at most finished in 3 months.

Therefore it is required that the bundle adjustment should be easy to use for error detection, for actually there is not much time left for that purpose in the workaday routine. Only if we succeed in meeting these time conceptions for important operating phases, will photogrammetry be a readily accepted partner in this complicated flow of work.

Dorrer

I think we must now close session V, although there is still the second question. I suggest postponing this question, unless somebody from the audience

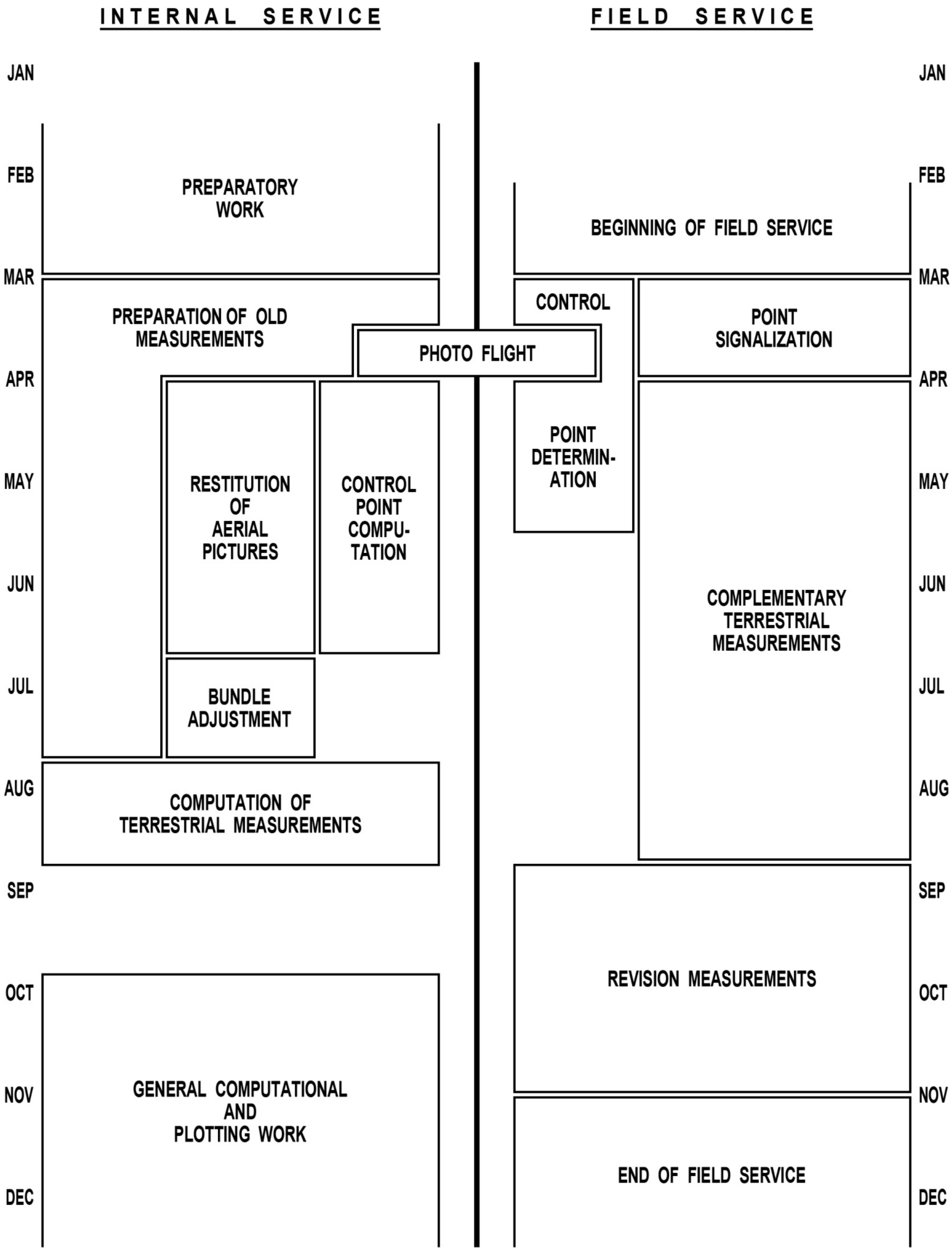

Figure V-7. Flow of Work.

would like to answer it in a definite way. The question is whether there is a need for reviewing presently existing standards for the combination of photogrammetric and ground surveys. I myself have the feeling that it is not necessary, at least not at the present time, to review these existing standards. But we should have a close look at them for their eventual revision in the future. Perhaps we can contribute something about that in the concluding session VI.

I am very sorry that we had to hasten through the current session at such a pace, but time has been running too fast!

S E S S I O N VI

INTEGRATED SURVEY SYSTEMS – RESEARCH REQUIREMENTS

Moderator	R. Adler (Israel)
Panelists	A. Chrzanowski (Canada) E. Dorrer (Germany) J. McLaughlin (Canada) U. Van Twembeke (Belgium)
Discussants	B. Dubuisson (France) J. Clapp (U.S.A.) S. Kuranchie (The Netherlands)

Concluding discussion on the questions:

(1) What are the major problems of integrated surveying and mapping systems which should be investigated further?

(2) Is there a need for creating an international study group, and if "yes", how should this group be organized and what should be its activities and its terms of reference?

SESSION VI

Adler

We have had a very interesting discussion during the past 2 days. I personally feel that I have learned a lot and I enjoyed the discussion. First of all, I would like to focus on the main points which were made during the debate. I think the first point made was the definition of the integrated survey systems suggested by Professor Konecny, namely that the integrated survey system can be classified as multi-purpose surveys carried out by different agencies referenced to each other, placed in a common framework, through a coordinated control system and permitting production of an up-to-date map for the purpose such as development surveys, property surveys, utility surveys, etc. As to whether the term multi-purpose surveys or integrated surveys is more suitable we might have reactions from the members of the panel or from the floor. Another main point was "what is the required accuracy for these multi-purpose surveys?" Were we speaking as was suggested by Mr. Polman about the relative accuracy between points of a different category or different meanings relative to higher order control framework? Many opinions were expressed, perhaps none more important than those expressed by Professor Dubuisson. He said that the accuracy should always be considered against the speed of the survey and I think that this is something that we should keep in mind. The second point was raised within quite a few reports on pilot projects, for the purpose of the evaluation of the suitability of photogrammetric surveys as a possible replacement for ground surveys, or perhaps, partial requirement of the ground surveys. I think that the results were very interesting and I feel that some work should be done to bring these various studies into a common denominator, especially from the point of view of the work involved and the efficiency. Perhaps we should also try and consider the possibility of using a monocomparator rather than the stereocomparator for making photogrammetric measurements, especially in view of the fact that practically all of the speakers on the photogrammetric side made a point on the precision reliability of the points. If that is so then the monocomparator could probably make a contribution. I don't know whether it could compete with the stereocomparator but it should be considered. Therefore work should be done to bring the sudies to a common denominator and perhaps initiate new ones.

The next subject was specifications for ground control surveys. I feel that there was a general consensus of opinion that it should lead to uniformity within an area or within a country, without trying to set up international standards for accuracies but trying to establish procedures for establishing a pyramid of accuracies within the ground surveys.

The problem of the cadastral information, the problem of multi-cadastral information could probably be expressed by overlay information on the lines that were expressed by Professor Van Twembeke where information was stored in a digital form in a computer and could be drawn and plotted according to the topic of interest as an overlay of a base map or perhaps a composite "sandwich" of overlays. This was demonstrated by Professor Van Twembeke, and I think that perhaps more work should be done on this important point. I think that there was a general agreement that we are in the process of switching over to a numerical definition of boundaries. However, the general consensus was that there was no possibility to run away from the graphical form. As someone quite rightly said the human being is an optical creature, and really we are sentenced for the next few years to combine the numerical information with some kind of a graphical output. Perhaps you would consider involving the orthophoto as a background, for presenting this numerical information, against the background of the photograph. I think that people are getting more and more educated in the art of interpreting aerial photography and perhaps the numerical information could be successfully presented in a graphical form against such a background. I think that perhaps more attention should be paid to the role of an interactive system, composed of a digitizer, a computer, some kind of a T.V.screen display and a plotter. This in no way contradicts what has been said about the actual acquisition method. This is simply a convenient means of handling the data coming in, but the origin of the data may be either photogrammetric or ground surveys. Perhaps an interactive system will solve our problems. It appears here as a very attractive means of presenting the multipurpose survey results.

Now I would like to ask the panel members to give their comments.

Chrzanowski

Really we have two questions to answer. The first question is: "What are the major problems of the integrated survey and mapping system?" Truly speaking I do not see any major technical problems because if somebody wishes to establish the system then, all the possible technical problems can easily be solved if we have enough money to do it. We have the technology, we have the knowledge and it is only the problem of economy whether we can afford to do it or not. There are however, still some problems which should be further investigated as they were outlined in the questions of the programme of our discussions. Altogether we had 12 questions which were discussed during the previous sessions. I think that we have not given satisfactory answers to at least seven of those questions.

In Session I, the question of "graphical vs. numerical information systems" still requires a clarification as to how to attack in the most economical way, how to define or where to place, the demarkation line between the graphical and numerical systems.

In the Session II, answers to the questions on the "off-line or on-line map production" were not too clear for me. Probably, it was for the reason that I am not a photogrammetrist. I believe, however, that there are still some investigations needed in this field.

In Session III there are still 3 questions to be answered:

First, the question: "How should the technological progress in ground surveys and computing be accounted for the standards and specifications for control surveys and detail mapping?" I think that some investigations should be made on how to incorporate the new technology into modern specifications. The same applies to the question on the accuracy requirements of the integrated systems. Although it is a question which probably should be separately answered for each individual country, at least some guidelines should be internationally established about the criteria to be used in the accuracy specifications and in deciding which accuracy is needed whether the surveyors should give the answer or the users should be asked? So there is a field for an international study. The same applies to the question: "What is the accuracy and density requirement of the control surveys?". As far as the density is concerned the answer is known. The density should be as high as possible but over here the question of economy comes into the picture. For instance, what kind of control should be established in urban areas in the developing countries which do not have yet any control? Perhaps they should not blindly follow the methodology which was used in the advanced countries which established very dense and precise control networks a long time ago. Details of the specifications may differ from one country to another but a general approach could be elaborated at an international level.

Finally in Session V the two questions have not been fully answered during the discussion. First: "What is the optimal combination of photogrammetric and ground surveys in the integrated systems?". We have learned from presentations about the achievable accuracies by photogrammetrists and by ground surveyors but these two groups are still working separately, they are not properly communicating with each other. There must be an integration basis established for these two technologies for data acquisition. Second: "Is there a need for reviewing existing standards and specifications?". I think we should look seriously at the question because if we are going to integrate the two survey methods (photogrammetry and ground surveys), then new specifications are certainly needed.

All the above problems require further investigations and, from my point of view, we should create an international group which could coordinate further research. The group could establish a central information office on all the pilot projects which are carried out in different countries so that all of those who would be interested in initiating new projects could easily obtain the information on: who is doing what and where in order to avoid a duplication of efforts. The group would also be responsible for drafting guidelines for standards and specifications for integrated survey systems.

McLaughlin

I think that there are very significant problems with respect to the design and development of such systems yet to be resolved. Our experience to date in Canada may be of some value in this respect.

The technical problems relate more to information handling and computerization than to the traditional concerns of surveyors. The fraternal concerns exhibited at this workshop as to which disciplines will be involved in control densification is not a significant issue.

Much more important will be the social and economic problems. Surveyors will have to become more cognizant of these problems, particularly in such areas as standards development and evaluation.

Van Twembeke

At this moment most countries do not have an integrated survey system. Most of the European countries have a graphical system built up over hundreds of years. This system is based on a geodetic and topographical point field.

Developing countries have to make a choice between a graphical, a numerical or a mixed graphical-numerical system.

Practically, I think that the final and most realistic solution is a mixed system in which the graphical solution is transformed gradually into a numerical-graphical solution. This transformation is of a dynamic type in which change for the better is a necessity.

Today we only have different graphical thematic documents set up by different specialists, such as pedologists, engineers, cadastral surveyors and others. But these documents present different accuracy characteristics, different scales, different sheet dimensions. In the first phase we have to put together all the information in order to get the first approximation of an integrated system.

The practical problem of graphical integration is to transform all these thematic maps into transparent overlays in order to adopt them to the new cartographic document, which in my case is the orthophoto map. Here I come back to the importance of a mathematically justified transformation method. There are different types of these transformations; in our case, the <u>anamorphotic transformation</u> gives us complete satisfaction.

In consequence of the complexity of a multi-purpose map, some remarks must be taken into consideration. The great amount of specific information needs the cooperation of scientists and technicians, working outside of the traditional cartographic field. The professional map-maker cannot solve the problem by himself.

The map-makers must know the needs of the map users which are often more concerned with specific qualitative information rather than with geometric or quantitative information.

The surveyor and the cartographer do not make documents for themselves but for different types of map users.

Remember, the users are more interested in imperfect information rather than in incomplete information. Thank you.

Dorrer

Although not considering myself an expert in integrated surveying, I can see a few problems, particularly in view of the very interesting discussions during the previous five sessions. And if you allow, I would like to indicate these problem in integrated survey systems – as I see them.

One of the major problems is caused by the present inadequate <u>up-dating</u> process of (analog) mapping information. One very vital prerequisite for an integrated urban mapping and surveying system, however, consists of the capability of quickly up-dating its own data bases (e.g. its digital files) for an ever faster changing environment. This in turn requires the machinery for continuously monitoring the relevant environmental parameters and for change detection.

A major problem lies in the acquisition, collection, storage, management, administration and general processing of the immense amount of (digital) data. Since the human still is the one who interprets the information, <u>interactive graphic data displays</u> will have to play a fundamental role in a user-oriented integrated surveying system.

A problem not sufficiently solved yet, at least not for me, is the distinction between absolute and relative accuracy. In my opinion, the term "accuracy" has been used in different ways during our discussions. This cannot be due only to the obvious fundamental differences in the data acquisition and measurement process between photogrammetry and ground surveying. In integrated survey systems, I believe, we have to entirely rethink and to standardize such terms as "admissible error", "error tolerance", "limit error", "error limit", "misclosure", "relative error", "absolute error", "root mean square error", et. al. The main difficulties occurring in network densification may then be appreciated by the surveyor, and hence be solved eventually automatically.

Another problem is, of course, the proper interface between, or optimal combination of photogrammetric and terrestrial surveys. We are pretty well on our way to deciding on an economic basis how far should we go with the ground surveys, and when should we introduce aerial survey methods. Nevertheless, in order to make full use of aerial photographs, photogrammetrically gained information must be employed much more intensely for integrated urban survey systems, e.g. for the multipurpose cadastre. Here, the orthophoto seems to have distinct advantages.

Adler

We welcome remarks from the floor.

Dubuisson

First, I want to pay your attention to the various aspects of the papers presented during this workshop. In particular, the discussion on the two groups of issues:

(1) nature and preparation of the map (type of map, cadastral or other, aerial or terrestrial surveys, ...)
(2) the network.

I want to emphasize the real problem of a network as a base to refer all other information including photogrammetry combines with remote sensing (Is it not the name of our International Society?).

Do you think that the main problem of integrated surveying and mapping is the type of photogrammetric base as a location information for the remote sensing?

The other thing concerns various opinions about accuracy. There exist various opinions but all of them are concerned with the conditions of Western Europe only. The real questions, however, come from other parts of the world, of which a very large part is very hungry. For this part of the world the question of accuracy of a few millimeters is perhaps not important at all.

Finally, to all these questions in the conclusions given a few minutes ago: we have many integrated systems to be thoroughly studied and compared, in order to make a catalogue of existing possibilities. From such a catalogue we then could make our optimal choice.

Clapp

The concept of the integrated land information system will soon be a reality – our attention must not be focused on whether they will develop, but rather on when and under what conditions.

The three crucial problem areas are, as I see it, those identified by John McLaughlin understanding the user and his needs; understanding the economic realities of any undertaking; and, understanding the institutional effects of any change.

The surveying profession must play a central role in resolving these problems, along with the planners, lawyers and environmentalists. This is our challenge.

Kuranchie

Mr. Chairman, listening to the reports and reviews of various photogrammetric projects in Germany and other countries, one comes to the conclusion that there is a breakthrough at last by photogrammetric methods so far as accuracy standards are concerned. I am sure that if those pioneer surveyors who toiled day and night to establish the spatial coordinates of the triangulation points we are now trying to check had had at their disposal the present standard reached in photogrammetry, they would never have used the classical surveying methods in determining the spatial coordinates of those points.

Thus having satisfied ourselves beyond doubt as to what photogrammetry can achieve in terms of accuracy and cost reduction, we should no longer concentrate our efforts in checking the accuracies of points fixed so many years ago since if anything at all we should suspect some movement of sorts.

Instead we should incorporate in our photogrammetric work certain checks on distances and angles so that in the overall assessment of block adjustment results we would have a better idea about accuracy both in absolute and relative terms. It is only by so doing that we can convince those concerned that photogrammetry can give us all the requirements we need for most of our cadastral and related works.

Thank you.

Adler

I feel that all the remarks which have been made in this session are very practical and I will do my best to present what we have said during this workshop as well as the concluding remarks to the FIG general assembly. Having consulted previously with Mr. Van Gent who was the leader of the working group on land information system we have problems of coordination with the FIG resolutions made in Wiesbaden. The group of Mr. Van Gent has concentrated more on actually providing the information to the user and organizing the dissemination of information rather than on the acquisition of data and processing of data. So I would have to consult with Mr. Van Gent first, but I am going to suggest to the General Assembly that a working group on the multipurpose surveys should be formed. Without any commitments, because it is not up to me to make the decision, I will perhaps suggest that Professor Chrzanowski, who has done a lot of the preparatory work, should take upon himself chairmanship of such a group with Dr. McLaughlin as a secretary and, of course, the secretary in such a group probably deal with the framework and would be instrumental in carrying out terms of reference. The terms of reference can, of course, only be decided upon by the leaders of the group itself. I would also suggest that probably Mr. Polman, subject to the agreement of appropriate organizations, should taken up the vice-chairmanship of such a group for two reasons; the first that he could work very closely with Mr. Van Gent and the second, I feel that after a suitable period, perhaps three years, after we formed the group, to shift it from Northern America to Europe and to have a new approach and a new reappraisal of the work that has been done.

I think that this is all we can say this time and I think that as chairman of the last session, I will permit myself on behalf of all of you to thank the organizers of the workshop, particularly Dr. Dorrer and Dr. Chrzanowski and their associates who have made this workshop a success.

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