ACSM
USGS

# International Conference on AUTOMATION in CARTOGRAPHY

Dec 9-12, 1974
Reston, Va.

# PROCEEDINGS

# PROCEEDINGS OF THE INTERNATIONAL CONFERENCE

ON

AUTOMATION IN CARTOGRAPHY

"AUTO-CARTO I"

DECEMBER 9-12, 1974

RESTON, VIRGINIA

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# Foreword

As is true for almost any department in life, you get out of a technical meeting as much as you are willing to contribute. Thus, looking back on the level of exchange--at the technical sessions and workshops, in the halls, around the bar--the International Conference on Automation in Cartography can be judged a profitable meeting. Many of the individual contributions were invited but many more were not, creating an atmosphere of discovery badly needed in a technical field as new and unarticulated as this.

The intent of the conference was to promote greater understanding of a rather new technology for the many users who are constrained by the lack of in-house research and development. Automation for cartography is the result of large R&D investments over the past 15 years; the something-for-everyone concept seems to have been put aside in favor of costly supersystems. While it appears that industry has responded only to the big spenders, a stable market for automated cartographic equipment and services will ultimately depend on the many hundreds, if not thousands, of low-budget users.

Credit for the innovative program format belongs to Warren Schmidt. He organized a blend of interactive panels, practical workshops, and tours which stimulated oldtimers and newcomers alike. Many thanks to Raynard Cardascia and Dan Garnett for their assistance in staging the technical tours. Bruce Palmer managed two shows of exhibits which gave the attendees many opportunities to look, touch, and absorb.

I want to gratefully acknowledge the support of those on the U.S. Geological Survey mapping research staff. Joyce Humphrey and Ruth Temple efficiently supervised finances and processed all correspondence. Marybell Peters and Robbi Jones made conference registration seem like fun, but in reality spent much of their own time preparing for and receiving over 400 people. Spencer Dean prepared the signs that kept the conference flowing between two separate locations, as well as other needed graphics.

I consider the proceedings to be one of the most important products of the conference, though there is always a tendency to underestimate the requirements of such a project. With skill and persistence (and despite such happenings as stolen tapes and a new baby), the staff Technical Information Office managed the critical tasks of tape recording (Bill Lynn), transcribing (Robbi Jones, Jacky Thawley, Wilma Donald), and editing (Madonna Elliott, Suzanne West) the proceedings of all panel sessions--word for word. In most cases, speakers' graphics were obtained and reproduced with high quality.

We are indebted to the American Congress on Surveying and Mapping and the U.S. Geological Survey for cosponsoring the conference, and to the following organizations which contributed significantly to its success:

Defense Mapping Agency Topographic Center
Defense Mapping Agency Hydrographic Center
National Ocean Survey
Central Intelligence Agency
U.S. Bureau of the Census

Any compliments concerning this conference should be directed to those I have named here, and any criticisms should be directed to me so that future meetings of this type may benefit.

Dean T. Edson

# Preface

About 500 pages of transcript of taped conversation were reduced to writing. The emphasis was placed on the exchange of information, and therefore these proceedings will appear more direct and simple than the participants will recall having spoken. Numerous times the *mot juste* had to be supplied for "thing"; despite our care in this respect, we undoubtedly have produced some misinterpretations.

Arrangements can be made for duplicate tapes--the originals are reel-to-reel, 3.75 ips, mono.

Madonna Elliott

Editor

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# Conference Opening

Dean T. Edson, Presiding
USGS, Conference Chairman

William A. Radlinski, Keynoter
Associate Director, USGS

Warren E. Schmidt
CIA, Program Chairman

Edson: My name is Dean Edson, and I am your conference chairman for the next 4 days. I am delighted to see the tremendous response for this conference, and I simply welcome you to the U.S. Geological Survey National Center. I hope that your next few days will be profitable, useful, and pleasant.

I want to recognize the cosponsors of this conference, that is, the American Congress on Surveying and Mapping and the U.S. Geological Survey. Many of you are members of ACSM and completely familiar with their scope of activities. ACSM's current president is Robert Reckert and I would like to note that Bill Overstreet of USGS will assume this post shortly. In so far as the Survey is concerned, you may also be aware that Dr. Vince McKelvey is the Director and I welcome you to the Center in his behalf. Without the cooperation and support of both ACSM and USGS, we simply could not put on an important meeting like this. The organizing committee also recognizes the many people, not only in Government agencies in the Washington area but also in industry, who have given of their time and talents to make this meeting a full spectrum meeting in terms of automation in cartography.

I was contemplating last night about what to call a group of people interested in automation in cartography. A couple of possibilities crossed my mind: the first was "cartographers of automation," but that did not sound very good; then I thought of "automated cartographers," but that sounded even worse. I guess the best way of recognizing the group would be to refer to them as "cartographers of the 1970's." Certainly the scope of our meeting has a lot of exciting ramifications; things are going on in the field of cartography that were unthought of just a few years ago. Perhaps after our meeting concludes we will have a better idea of what the future might hold.

I think everyone should start a meeting with a wornout joke. This particular one concerns obtaining expertise in the year 3000. Instead of going to the university, you simply go to the brain bank, shop for the kind of brain that you want, and have it installed--a savings of at least 4 to 8 years. In this particular case a young man went into the brain bank to look at the price list. The attendant was going through the catalog, commenting that an engineer brain would cost $350/oz; a lawyer brain cost, $375/oz. If you wanted a technician brain, the cost would be considerably less. When he got to the cartographer brain, he quoted the price of $850/oz installed. The young man was astonished: "My gosh, that can't possibly be right." The attendant replied, "If you had any idea how many cartographers had to die before we get an ounce of brains, you would understand why it costs so much."

The 1970's hold significant potential in the field of cartography. Before I launch this meeting I would like to quote from a recent ad by a prominent computer manufacturer in Smithsonian Magazine, really a sign of our times. It stated simply that in 1952 the cost of processing or performing 100,000 manipulations on their particular computer was $1.26; in 1958 the cost dropped to $0.26; in 1964 it dropped to $0.12; in 1970, to $0.05; and now the cost of 100,000 manipulations is a penny. When you think that over the last 20 years our consumer price index has gone up 80 percent, you begin to get the feeling there is indeed tremendous potential for this gadget called the computer, particularly in the field of cartography. At some point, which I believe is now or at the very least in the foreseeable future, cost-effective computer operations will certainly be realized. No wonder people are excited about the possibilities for automation in cartography.

Before I get on with the meeting, I would like to introduce one of the principal actors in this unrehearsed play--Warren Schmidt of CIA. (Editor's note: Schmidt is now employed by USGS.) He will be your program chairman during the conference and will have much more to say to you a little later on.

We are fortunate this morning in having a keynote speaker who can focus for us some of the real problems facing cartographers today. He hails from New York where he earned a degree in mathematics from Hofstra University. And he did a considerable amount of graduate work at Georgetown University in astronomy. He received two honorary awards--Kappa Mu Epsilon and Pi Alpha Theta--during his academic career. His introduction to topographic mapping came as an officer in the U.S. Army during World War II. After working for the Army Map Service a short time, he joined USGS in 1946. His illustrious career has been marked by many awards for outstanding work primarily in the field of cartography. He has held key positions in ACSM (such as chairman of the Cartographic Division of ACSM) and in many other professional societies. He is the author of numerous published articles, and he was, I believe, an editor of Photogrammetric Engineering some years ago. Having represented USGS at conferences throughout the world, you may recall that he moderated the USGS and London Royal College of Art Symposium on Map and Chart Digitizing held in 1969 in Washington, D.C.

Most important, though, is the fact that our keynote speaker is currently the Associate Director of USGS and is thus in a position to be keenly aware of today's problems and potential methods for their solution. It is my pleasure to introduce the person that everyone in USGS calls Rad--William A. Radlinski.

Radlinski: I believe the first thing one must do when he keynotes a cartographic conference is to define his terms, because there are so many different "official" definitions. According to an old USGS definition, modified by me for this paper: "Cartography is the art and science of expressing graphically or digitally, by use of maps, charts, or other display, the known physical features of the surface of the Earth or extra-terrestial bodies and the works of man and his varied activities." Classically, cartography is the art of map construction and the science on which it is based. I will direct my remarks to map construction and digital aspects of the art, including the traditional color-separation drawings and the modern numerical data in machine-readable form that are the building blocks of map construction. Some of the more technical people call this "symbolized geographic feature display." I will also talk about the direct use of digital data.

Since I've started with a definition, I had better go all the way and also define what is meant by automation. Automation here will mean exactly what it does in most other disciplines--the science of operating or controlling a mechanical process by highly automatic means, such as electronic devices.

Now let's ask ourselves why we should automate cartography, for if we don't have some good answers to that question, we might just as well end this conference now. After all, automation is not a universal cure-all because it is usually very expensive to install, can cause labor problems, and sometimes results in a reduction in quality of the final product. However, when one considers the magnitude of the workload facing the mapmakers of the world, automation may be the only way to get the job done. The enormity of the task was quantified by Professor K. A. Salichtchev, immediate past president of the International Cartographic Association, when in 1971 in Paris he said:

> To solve the problems that confront humanity, we must know our planet, its structure, conditions, natural wealth, the distribution of the population and economy; therefore, we must possess and keep up to date a multitude of maps. What is the actual number of this multitude? I shall cite only topographic maps covering the Earth's land areas as an example.

Salichtchev then established a reasonable basis for estimating the number of maps that will be needed and concluded:

> Under these circumstances it will be necessary to publish more than 1,000 updated topographic maps every day. Then again, how the figures will increase if we take into account thematic maps and ocean charts. The execution of such a task is inconceivable without automation!

Closer to home, it may come as a surprise to some of you that 21,600 of the 54,000 7.5-min-quadrangle, 1:24,000-scale maps it takes to cover the lower 48 United States have not been published, and of the 32,400 that are published, 8,000 need revision. At our present rate of production, it will be 1984 before all of these maps are published and before the backlog of out-of-date maps is eliminated through current revision.

I can think of more specific reasons for automation:

--To speed up the mapmaking process.

--To improve the economics of mapping.

--To generate digital data for direct dissemination and rapid manipulation to produce, with a minimum of effort, maps at different scales and with selected contents.

--To facilitate map revision.

--To reduce the incidence of errors.

It seems to me that any one of the cited reasons, if valid, is sufficient to justify automation, but when combined, the case becomes overwhelming. The relative importance of these reasons will vary among mapmakers and users, but the order in which I have given them is my priority. You may have other reasons for automating cartography that we will learn about later, but for now I would like to talk about the five I have given.

1. To speed up the mapmaking process.--It is interesting to note that the glossary of "Automation Terms in Cartography," published by the International Cartographic Association in 1973, defines automated cartographic systems as, "automated methods of producing charts and chart products, in graphic and digital form, with the view of radically reducing total production time." It would seem that, by definition, ICA is also saying that the number-one reason for automating is to speed up the process of mapmaking. Consider, for example, the bad news from the mapping program of the Geological Survey. On the average, 59 months are required to complete a standard 1:24,000-scale, 7.5-min quadrangle map. Nearly 5 years is a long time to wait for a final map, not to mention what happens to the currency of the content in that time. The inevitable result is that the map is out of date--sometimes grossly so--by the time it is ready for use.

Breaking down these 59 months, we find the following elapsed times to carry out the various mapping phases (these are figured on a project basis for an annual production of about 2,000 maps; a project may consist of 4-40 maps and will average about 20):

| Phase | Months |
|---|---|
| Authorization and planning | 1.5 |
| Photo delivery time | 9.6 |
| Ground-survey control | 11.5 |
| Photogrammetry | 8.7 |
| Field completion | 5.6 |
| Cartography | 14.7 |
| Reproduction | 7.4 |
| | 59.0 |

Most of this is shelf time with the map on the shelf awaiting its turn to enter the next phase.

Time savings in the mapping cycle can be realized by more careful planning and programing but the significant improvements will come from better technology, such as automation. Not only will the individual phases be carried out more rapidly, but shelf time will be reduced because the map will not have to await the attention of a skilled human technician. A specific example would be the recording of selected map data directly from the stereoscopic model in digital form for use in the automatic preparation of the color-separation graphics.

2. To improve the economics of mapping.--In these days of spiraling costs, economy of operation is an attribute dear to everyone's heart and a real prime mover toward implementing automated techniques. Not too many years ago when people presented papers on the subject of automation, they avoided the cost effectiveness factor like the plague. Today, it is a different scene: equipment effectiveness is rising with ever-increasing speed to the point where, in spite of inflated hardware and software costs, new techniques are truly competitive.

USGS costs for the standard 7.5-min, 1:24,000-scale map in the United States are:

| | | Cost | Man-years |
|---|---|---|---|
| New map | | | |
| | Average | $17,000 | 0.7 |
| | Range | $13,000 to $25,000 | 0.5 to 1.0 |
| Revision | | | |
| | Standard | $12,000 | 0.5 |
| | Interim | $ 1,900 | 0.07 |

(Standard revision is a complete reworking of the map, including field checking. Interim revision includes only those changes that can be made from aerial photography, with no field check; the new information is overprinted in purple on the old map information.)

These quadrangle costs translate into an average cost per square mile for new mapping of $304, ranging from $241 to $470/mi$^2$. The direct man-hour cost averages about $13/mi$^2$.

Despite continually higher costs of equipment and manpower largely due to inflation, overall mapping costs at USGS have not risen because of our increased efficiency. But there is reason to believe we can reduce these costs significantly by using new technology and present personnel.

3. To generate digital data.--It has been estimated that the average U.S. topographic quadrangle contains over 100 million separate bits of information, more than the average map reader could absorb in a year's time, and the topographic sheets of many other countries contain even more. While maps are extremely efficient devices for the storage of spatially associated data, even more information about an area together with positional coordinates can be stored in computers.

A major advantage of cartographic data in digital form is the convenient interface with other geographically related information and management systems. Such interfaces provide a means for numerical data in machine readable form to be utilized in complex modeling and problem analysis. Examples of the type of data required for various systems include: positions and elevations of manmade or natural features, transportation routes, lakes, streams, shorelines, slopes of terrain, land use, cadastral and political boundaries, population distribution, soils, geology, hydrology, and flood-prone areas. When these data are digitized, the end product can be in a variety of forms and at any scale.

It is reasonable to assume that nearly everything that is constructed by man is known at some level of government. We therefore must strive harder to seek ways of accessing local government data in an effort to achieve the goal of best information for the least possible cost. And for greatest utility, such data should be collected and disseminated to users through a central coordinating mechanism such as the Survey's newly established National Cartographic Information Center.

Another advantage of digital data is that it can be manipulated rapidly to produce, with a minimum of effort, maps at different scales and with selected contents. In the past, cartographers have mapped specific areas of interest at a scale commensurate with the units in use that best satisfied the average map user requirement. As such, the level of content was, of necessity, limited by the scale selected. Past technology has also condemned the end product to be a hard copy at a single scale with limited and generalized content.

Far too often users have found it necessary to produce their own maps because of their need for specific content or particular scale. Of course the scale of the general map can be changed by using a copy camera, but the content must be treated separately and manually. These analog processes are sometimes expensive and limited by optical or mechanical constraints. Today, automated techniques in cartography can be applied to develop new and different forms of presentation.

4. To facilitate map revision.--Maintaining existing maps is often just as important as compiling new maps. Several methods for revising maps are in use today, each requiring review of recent source material and manual cartographic procedures. With the digital computer, automated processes are seen as the ultimate means of map revision in the future. In digital form, cartographic information can be updated continuously from reliable sources, permitting current graphical display on a truly timely basis.

We have a research effort underway to develop a process utilizing automated cartographic techniques specifically aimed at map revision. Again, digitization of the existing map is necessary. Digitized source material is then merged with the digitized map data, and the results are edited and transformed to high-quality graphic form by means of automated plotting equipment. However we are not sure whether it is more cost effective to store map data in digital form and update the data bases prior to producing a revised map, or to store map data in graphic form and convert the base to digital form prior to incorporating new data. The door of opportunity is wide open for innovative developments in this area.

5. To reduce the incidence of errors.--To produce an absolutely perfect map or chart must surely be every cartographer's dream. We have always accepted this dream or goal as being unattainable. Additionally, the degree of perfection or tolerable amount of error is tied closely to economics.

Automated cartographic techniques may help us on both ends--providing a more reliable and complete product at lower cost. While accuracy is normally limited by the inherent capabilities of the various machines utilized, reliability and completeness are a function of costs and human judgment. Each phase of mapping that can be removed from the frailties of human judgment and be automated is likely to become more error free.

Summing up, the introduction of automated procedures to mapmaking and map maintenance presents a whole array of opportunities to improve the cartographer's art. It can eliminate vast amounts of tedious work and cut years off the time presently needed to produce new maps. It can mean the timely updating of existing maps. It can permit the cartographer to be much more responsive to the demands of map users for special content or scales. It can provide access to extensive data which are not now used effectively because by present methods of data gathering and accession they cannot be assimilated economically in the mapmaker's data base. And it can do all these things faster, better, for less cost, and with less chance for error than they are now being done. The use of automated techniques in cartography can be likened to letting the genie out of the cartographic bottle--releasing a giant slave whose services may be utilized almost at will. It is a rose well worth pursuing.

Now, let me tell you that I was once a mathematician (when you reach the management levels of Government, you no longer are anything you once were). In those "good old days," I could put just about anything in life into an equation. I'd like now to revert to my past and put some of my thoughts on cartography into the following equation:

$$MV = f\left(\frac{C_1 \cdot C_2 \cdot C_3}{T}\right)$$

What this equation says is that map value is a function of content ($C_1$) times completeness ($C_2$) times clarity ($C_3$), all over preparation time (T). You will note how readily you can increase map value by reducing the preparation time, or vice versa.

Some of you may think that we have a good equation--that's just great, but I would be surprised. Others of you may think that it's only a partial equation and that map scale needs to be factored in--that's okay too; I think scale could be a factor. Still others may think that I may have <u>been</u> a mathematician but time has dimmed my memory--because those <u>should</u> be plus signs in the numerator, not multiplication signs. If you fall in any of these groups, I'm glad because I've got you thinking about the problem, and that, I believe, is what a keynoter should do. In your closing session, you will be better able to establish the function more precisely. Good luck in your deliberations.

Schmidt: When we originally planned this conference, the idea was to examine automation in cartography with emphasis on the current state of the art (that which is operating and available). We were trying to cover the topic comprehensively--it's a very complex one--and to provide maximum interchange between participants. To do this, we considered different approaches: strictly presented papers, key papers and panels, and the informal panel. Looking back for a model, the 1969 Symposium on Map and Chart Digitizing and the 1970 International Geographical Union Conference on Geographical Information Systems have been successful meetings with a great interchange of information.

We also had some other purposes in selecting the panel format; one of them was to avoid the problem of clearing the papers, especially in the military mapping and the intelligence agencies. The panel format avoided freezing the topics 6 months before the meeting and does foster greater interchange between the panelists and the audience themselves. However, for this meeting to be effective, I will ask the cooperation of the chairmen, the panelists, and the audience in several ways. First, I will charge the panel chairmen to keep the dialog going and to keep on the subject. Because this is being recorded, we will ask the speakers to identify themselves, and if they don't, the chairmen should ask them to do so. Lastly, if possible, stay within the time limits. I had considered bringing a whistle, but I hope it won't be needed. I will ask the panelists to keep to the point, to identify themselves, and to avoid commercials. This is not aimed at the business people but at everyone; we all like to sound the trumpet for our own organization. Lastly, I will charge the audience with several things. First, when asking questions please identify yourselves because we want the discussions in the proceedings. Second, please be patient--if something is not covered or is unclear, please speak up. If it is not covered in depth, realize that we are just sampling--there will be opportunity to do this later, perhaps by seeking out the speaker. Lastly, I will say that most of the people that are active in automated cartography are in this room, and therein, I think, is your greatest opportunity--that of meeting and talking with these "activists."

Before starting, one quick word about the workshops and the tours. We do have 4 tours: one to Suitland, Md., to see the Census Bureau and the Defense Mapping Agency Hydrographic Center, the second to the National Ocean Survey in Rockville and the Defense Mapping Agency in Glen Echo, the third to the Engineer Topographic Laboratories, and the fourth one here in the Geological Survey. Among the workshops we have INPOM--Interactive Polygon Mapping System--created by Harvard Laboratory for Computer Graphics and Spatial Analysis. This is an interactive display of polygonal information, manipulations, and pattern fills. Also there are some samples of ongoing work. The Bureau of Census DIME system will not be a primer but rather a problem workshop; you will be expected to know something about DIME. The CAM system, from CIA, is available but will be limited by space. No one will be able to participate in all these tours or workshops, so you must make a choice among the opportunities on Tuesday and Wednesday afternoons and Thursday morning. Please sign up for the tours at the registration desk.

To open the sessions, I would next like to introduce Dr. A. Raymond Boyle, who will chair the sessions on hardware. Ray was associated with the Oxford system in 1960-1964, and in 1965 he immigrated to Canada where he became a professor of electronic engineering at the University of Saskatchewan. He worked on the Canadian Hydrographic Service system until 1970 and since then has been the leader of the Graphic System Design Applications Group at the University of Saskatchewan. I think that Ray could best be called "Mr. Hardware," and that is why he is here.

# Hardware Sessions

## Introduction to Hardware

A. Raymond Boyle
University of Saskatchewan

Boyle: It is a great honor to be asked to come here--I always enjoy these meetings. I am noticing the increase in automation since the last meeting USGS hosted in 1969. For the recording of the session, we had a very nice court stenographer hammering away on a little shorthand typewriter (and those of you who have read the report know what a wonderful job she did, and after editing, how interesting it made the reading of that meeting). Today, we have automation--tape recorders rolling away--and I hope we can maintain the same standard of reporting that we had at that other meeting.

My job is just to give a 15-minute introduction. We have a little extra time, but I am not going to use that up. I want to mention the meetings we have had for the International Geographic Union in Ottawa in 1970 and 1972 from which two books were produced. This Commission of the International Geographic Union, in which I am involved as a hardware person, is producing another book for next year. For this, I want to make certain, as far as hardware is concerned, that I am up to date with all those people here who have hardware systems in cartography or in geographic information systems. While there are not many geographic information systems with special hardware at the moment, I want to check that we are as complete as possible. I have two of my engineers sitting in this hall and a geographer from the University of Buffalo; they will buttonhole the people we know for a few minutes to ask if the information we have about their equipment--the control software and any special software--is correct and up to date. So I hope you will be kind and just tell them. It will only cover about 10 or 12 lines in the final copy, but we want it to be correct. This is a wonderful opportunity to take advantage of the people who are here. If anyone thinks they may not have been reported in any of the publications before, and has something interesting in the way of the subject matter, please make contact with me, Duane Marble, or Roger Tomlinson. Thank you.

The chairmen and the panels have had their instructions. They are here to stimulate discussion among you. These meetings, with discussion from the floor, are very important. All of us who were at the 1969 meeting were converted, maybe foolishly, to the fact that automation was going to occur. I think that we have been proved right over these years, but this is arguable. As this meeting is larger, it may mean that there are more people who are converted, or it may mean, and I hope it does, that there are people here who are not convinced of these ideas. Interaction between those who believe, those who have ideas, and those who do not believe is the central theme of this meeting. It is your meeting, not just for the people sitting up here on the panel--they are only instigators of discussion. I really hope that the panels, the chairmen, and you as members really take advantage of this opportunity for discussion. As a university professor, I am pleased that the attitude of lecturing is disappearing; in fact, this year I am finishing my last purely lecture course. I now conduct interactive courses and I find this wonderful. Some professors do not like this method, but it certainly makes, as far as I am concerned, good engineers--not people who have just sat, listened, and mentally recorded information. We know that they can use it by the time they finish this interaction, and I hope that we can get the same atmosphere into this meeting.

You will find that the people we have chosen for the panels have strong opinions; this is one of the reasons they were chosen. One reason I am here is that I am quite content to state my own opinion, for better or worse. I am perhaps in the fortunate situation that I do not have anyone, any massive organization over me to answer to as long as I am ethical in what I say. I do not have to follow any party line--it's my own judgment and the judgment of the team members I have in my group who help me in these ideas. All the people on the panels were asked to come because they have strong views, have good ideas, and are good thinkers. Make them work; make them bring out their ideas.

We are certainly in need of more transfer of information in automated cartography; we are trying to help with the International Geographic Union book. To those people who have useful, written articles, I hope you will make them available and let other people here know what is available. Our group will produce a list of available articles, and I am asking that the audience and all other panels do the same. I think this interchange is extremely valuable.

I specifically asked people from industry to come along on the panels today. I have spent about a third of my life in industry. At many meetings, particularly on automated cartography, there has been too great a preponderance of users in government and not enough of the people who are actually doing the gutsy, very often unappreciated work in industry. These are dedicated people with brilliant ideas, and you can learn so much about what is possible and what can be done from them. I am sure their participation will add to the conference.

We were talking about the audience and whether or not they were converted to automation; I hope that here in the audience today we have many cartographers in the older sense who do things by manual means. I hope that we will be getting an interchange between these two types of people. If you do not believe in what is said this week, I ask you for a minimal appreciation of the fact that other people use or will be using your data. I could go on talking about this for hours, but I will just give you one example. Please remember when you are preparing your data (assuming that it is useful data, and I hope that there is no cartographer here who makes useless data) that somebody will be wanting to digitize it. If you put labels across lines on the same overlay sheet, you have made problems for people afterwards. An extra $10 on another piece of plastic for another overlay sheet may save a couple of thousand dollars of digitization work later on. Now, I could go on with many more examples but I hope that comments will be made about this in your cartographic groups. The preparation work that we now have to do on overlay sheets from the mapping agencies in order to make them easier to handle has raised this issue to importance.

We have been going through a considerable number of trials and tribulations about hardware over the last 10 years. Some people have jumped into getting hardware at too early a stage just because they had the money. Some did not really think in terms of having a hardware system--they put bits together which were incompatible, and so on. Other people just did not plan properly, and we have a large number of pieces of hardware around and even in use which are not very useful. We have been through a learning stage. There has also been a stage over the last 10 years where the reliability of the equipment has changed from a very debatable factor to something that is fantastically good. Ten years ago anything mechanical was good and reliable, while anything that was electronic was "maybe it will work, maybe it won't work." Now the reliability of electronic equipment has far, far surpassed anything imagined in reliability and far surpassed mechanical work. I, for one, appreciate a mixture of the two, but I generally try to avoid mechanical options and replace it with electronics. This is a change in the state of the art of hardware; I expect many people still find it difficult to believe this change, but it is true.

When you purchase equipment, please make certain that you do a proper system design and that you have properly analyzed your use. It is absolutely vital if you are going to be satisfied. Make certain that you can have good maintenance of your hardware. In cartographic establishment (and I know quite a number that have perhaps $2 million worth of equipment and not a single screwdriver in the building) it is quite a problem because these are complex hardware systems which must be maintained.

Changes have been coming about in the last few years. There has been a change from user development to a professional approach. I selected the order of the panels today, and you may think it rather strange that we start off with output devices. You might say why don't we start off with input and move through a sequence of events? Well that is the normal way, but I said no; I do not want it that way for a very good reason, in my opinion. The actual drafting side has become, over the last few years, a much more professional activity than the digitization and the interactive editing side. The latter are much newer, need more work, and are changing. For a number of people and for a number of years, automated drafting has been a truly professional activity--no doubt about what happens, no doubt about accuracy. Thus more is known about it, more assurance is there--I thought that I would have that first so as to begin on solid ground. Then we will go into the other things which are partly good and partly debatable and where I myself believe that the problems are essentially finished although we need a couple of years to finish them off. We will talk more about that in later sessions.

We will talk much about the advantages of humans, the advantages of machines, and of course the great advantages of interaction. Whatever you are doing, use the best of the machine and the best of the human--these two working together are the most exciting. We are now breaking through, but it has been a very, very exciting battle, trying to make the best of the two for cartography.

I have talked about the importance of defining the real need. However today we are going to assume that when you have said that you want something, you want it. I hope that this aspect is discussed in some of the later sessions. There is one issue running through the whole system of cartography, from the beginning to the end--you need clean data. Many people have not paid enough attention to the cleanliness of their data. You should do this in the digitization--use and produce clean data. If this cannot be done, you should clean it up as rapidly as possible. I feel this is a thread that should run through all our work; if the equipment will not handle or produce clean data, be suspicious.

I am going to give a short introduction to each panel, and then become one of the perhaps more obnoxious members of the public. If any awkward questions should be asked, I will use the opportunity to keep the discussion thriving.

I have been in automated drafting for a very long time. I put the first drafting table on the first digital computer in Britain--that was quite a long time ago. You can imagine all the clanking relays that went onto that machine. It has been very delightful to watch the wonderful machines which are now made for this work. As long as you make up your mind what you want, you can get high accuracy or high speed; usually you must realize that you cannot get both quite at the same time, although the high-speed systems are now reaching higher accuracy and vice versa. It has been very interesting to watch some of the breakthroughs, particularly in 1964 when purely digital plotting--the CalComps and the Gerbers--started. If any of you are small users of cartography and drafting, I would suggest that you do not get into the business of precision automatic drafting. If you are big enough to run two shifts per day, fine; but if you are the small user, I would rely on someone else to do your drafting. It is a tough professional activity to do it well; unfortunately, at the moment there aren't any good commercial groups providing this service. Government departments tend to be overloaded if you are not in their department, but I hope that such contract groups will arise.

There is no major cost problem in automated drafting; it is now down to the hundreds of dollars per sheet. There are no major problems; the problems which will be talked about in the next hour are problems of increasing the flexibility of these devices. We are going to cover all the latest methods, not only the old x-y drafting units, which are extremely good and are perhaps the most commonly used at the moment, but the newer drum scanners, laser plotters, microfilm units, and additions to the x-y plotting systems.

## Output Devices Panel

W. Howard Carr, Presiding
USA Engineer Topographic Laboratories

John Constantine
SELCO-Constantine Engineering Laboratories

Thomas J. Healey
MBA Information Systems

Edward Snow
RETICON

Patrick Grosso
Image Graphics, Inc.

Peter G. Wohlmut
i/o Metrics

Carr: According to Ray Boyle, good interaction makes good engineers, and this morning we are going to make you good engineers because I want you to interact with our panel members. We are blessed with a variety of technical talent here; you are looking at presidents and vice presidents of corporations, representing five technologies. These gentlemen have come on their own time, spending their own money, from all over the United States. As Ray said, we are going to let them talk to you for a few minutes, and then we would like you to ask them questions on an informal basis.

The first speaker today is John Constantine from Constantine Engineering Labs. John is the president; he has several sons that are running different parts of his organization in California--from California to New Jersey to Pennsylvania. Paul, one of his sons, is installing some equipment today, and he said, "Dad, you go talk and I will install hardware." John, I turn the floor over to you for a talk about precision cathode-ray tubes.

Constantine: I appreciate the opportunity to come and discuss what pertains to our model--the latest in the science of electron beam control. I would like to tell Dr. Boyle that I was converted about 25 years ago regarding the precision requirements in cathode-ray-tube (CRT) technology. Basically, we were manufacturers of deflection yokes that are required to deflect the electron beam on the face of the CRT. The precision had to be commensurate with the output on the face. Since we are going to discuss output devices, it is a little bit difficult to determine just which is the output device in these automatic loops. Rather than trying to label any one component, we will just jump 25 years when CRT's had *spot sizes* of 5 mil for the flying-spot scanners to today where we discuss 0.5-mil or 12-μm spot sizes on the face of the tube. That implies that all the components behind the face, including the computer that has to drive the amplifiers to position the spot, must have a precision commensurate with the 0.5-mil spot compared to the 4- or 7-in total deflection. That works out to a pretty small percentage of precision.

The uses today, where we have built equipment, are for such applications as the quick-look monitor for the ERTS system, which takes the data from the ERTS satellite and converts it to a 70-mm photograph negative which is then enlarged to 8.5 by 11 in. In this ERTS system, we are discussing 0.6 mil on the face of the CRT (that's on a 3- by 3-in raster which implies 5,000 lines) with a reduction of .75 to the film plane; you are looking at a lot of detail. We have a photo of an ERTS picture of northern California which shows Lake Tahoe from 600 m. That represents a 4,600-line capability on the face of the tube. Once it goes through the lens and onto the particular RAFR film, you get down to possibly the resolution capability of 1,200 lines, which is quite a loss through the lens and film system. The Goddard system, which is going to be used for some application requiring a film recorder, is able to record on that film a 4,000-line raster and actually resolve them on the film. In a period of a couple of years we have made quite an improvement in the output devices capability from the face of the CRT to the film. We are starting off with a 0.55-mil spot and winding up with 4,000 lines on the film. As Dr. Boyle said, the problem is getting rid of the noise.

ERTS requires gray-level capability on the output of the CRT and onto the film. The digitization there is much more difficult than straight black/white digitization. In that area we have recently delivered a large-format scanner capable of scanning a 14-in-square master letter; that is digitized, stored, and then played back onto a printer. These letters are actually used for generating the masters on the phototypesetting equipment. Originally these are 12-in-square letters that have been made by hand, and the object is to digitize them, store them on disks and tapes, and then play them back on a precision printer. We have the capability of digitizing the letter that is 12-in square, storing that data, then playing it back on the printer which can produce up to 256 characters on a plate that is about 6-in square. This is another area where the CRT, optics, film, and computer are all tied in. The output is actually the glass plate that goes into the phototypesetter. Another area is the reverse--digitizing for X-ray scanning and enhancement. The other end is going down to the microscopic area where the CRT raster is focused onto a small section that you wish to examine, such as cells or chromosomes. That information can be stored and operated on similar to any other type of digitization. All of these things have to be done with precision that is commensurate with the percentage, resolution, and gray levels that you are looking for on the final output.

Boyle: One of the most interesting aspects is the use of the precision CRT as the photo light for x-y recorders, which you have been involved with. Also I think it is one of the most exciting developments, to get to the flexibility of any sort of symbol plotted on the x-y tables.

Constantine: The system used at Ft. Belvoir was capable of using a 2-mil spot with wobbling to produce circles. In that manner they were able to use it for filling in letters and plotting and transferring the letters on the map section. We won't consider that particular high-resolution application.

Carr: For those of you who will be visiting the Engineer Topographic Laboratories on Wednesday and Thursday, this hardware will be shown. It is a subrow system of positions on the Gerber plotter, and we will be driving the hardware with minicomputers talking to each other. This is a chance to see it in operation. As John indicated, there are two problems: one is getting resolution and one is getting too much resolution. If you make the spot too small, then you have to do something to generate wide lines. This gets into something that you never really see on the surface until you dig a little deeper. If you put a 2-um line down and you try to generate lines which are 25, 100, or 200 μm, you've got to move that spot around to do what we call "dittering" or "diddling." You have to control that spot to generate all of the lines and all of the symbols that you need to work without the map machine.

With all the work that has been done between SELCO Labs, CBS Laboratories, and another electronics house that we don't have a representative from--Adage--as well as amplifiers and data handling hardware built by us, I strongly recommend that you see this system in operation. As far as I know, it represents the state of the art of CRT's applied to a plotting operation.

For the past several years there have been quite a few developments going on in drum raster plotters--large, rotating, mechanical drums on which you can either wrap film to output or you can wrap documents to scan. One company that has been doing considerable work in this area is MBA Information Systems, which currently has two projects going on large drum recording devices. Tom Healey will be talking about some of the work at MBA. Tom is basically a businessist who has gotten into auto-mechanical hardware in the past few years. His background has lead him to be manager of MBA's Electro-Optical Systems Group. I'll leave it to Tom to tell us the details.

Healey: I will address raster drum scanning and recording devices, primarily raster scanning technology touched on previously by Constantine.

(Figure 1) Talking about raster map production devices (Ray Boyle indicates that the smaller users would go to services bureaus), the raster plotting devices are a fairly large investment. Therefore, you will probably only find major use within the large-volume production facilities. Large volume is defined as the ability to generate a full set of 4-color separations for a 42- by 60-in map within a half a day, or specifically 2 full-color maps in one 8-hr day or approximately 1,000 full maps per year on 2 shifts. The raster finishing or raster scanning plotter has a cartographic resolution, accuracy, and registration. The specific device that Howard Carr referred to has 800-line/in resolution and 0.5-mil accuracy. Registration is 0.5 mil and repeatability is 0.5 mil, all referenced to the recording surface--7-mil Estar lithographic film. This film is very flexible and must be handled very, very carefully, as you well know, in order to make it meet these requirements. These are some of the parameters that make raster scanning very attractive.

Area fill can be accomplished by software instruction within raster scanning and plotting. The problem inherent with the vector-type devices does not exist, that is the fact that one has to scribe, scribe, scribe, and scribe some more to effect an area fill. In

## CHART PRODUCTION FEATURES OF RASTER TECHNOLOGY

HIGH SPEED LARGE FORMAT PLOTS (FULL SET OF COLOR SEPARATION IN 4 HOURS)

4000 COLOR SEPARATION/YEAR

FIXED THRUPUT (PLOT TIME FIXED AND INDEPENDENT OF COMPLEXITY OF DATA)

LARGE AREA FILL IN ONE STEP (DOES NOT EFFECT PLOT TIME)

ELECTRONIC HALF TONE GENERATION

CARTOGRAPHIC QUALITY

| | |
|---|---|
| RESOLUTION | 8001 pl |
| ACCURACY | $\pm$ .001 |
| REPEATABILITY | $\pm$ .0005" |
| REGISTRATION | $\pm$ .0005" |

Figure 1

raster this is done in one step in software; software-generated halftones are being generated now.

Another thing we've done with raster scanning plotters is to use a laser to record directly on offset plates as well as lithographic film. The hardware (fig. 2) for this device is simply a disk-operating system with minicomputer control that works offline in this particular system. This system is under contract with the National Oceanographic and Atmospheric Agency, National Ocean Survey (NOS). The original data, that is the digital data, that we were talking about before is taken from their 360/195 and put onto magnetic tape for input to this system.

The raster drum plotter features (fig. 3) are 800 lines/in resolution, 3-mil spot size, 42- by 60-in recording on 44- by 66-in film, offline production, and the option to upgrade to a scanner plotter. Film is loaded on the clamps. All the energy from the laser and the laser light is behind the drum to comply with OSHA safety rulings. The drum has a 90-in circumference and can take 70-in or 76-in film.

There are several significant factors of a raster scan system (fig. 4). The drum plotter can be upgraded to a scanner. The scan spot size is 3 mil, and the input graphic size could again be 44 by 64 in. The scan window is 42 by 60 in, and the scan time would be 1 hr per film record. The old original graphics (specific production negatives) could be scanned and then merged on an interactive display with data from updated information.

The scanning resolution on the device in figure 5 is 800 lines/in. It is possible to change scale from a half to a factor of 2. The system has tolerance scaling that is anamorphic, and there is the ability now to add a hardware multiply-and-divide to do interim scaling from one data base to another within that range. As the computers and some of the other devices become a little bit more powerful, we will be able to scale even more. The scanner/plotter inputs would be digital data, either coming directly from a digital data base on film or on magnetic tape or the analog data from previous records. The outputs, again, can be either digital data or analog data.

We are presently building a scanner/plotter for the Rome Air Development Center (fig. 6). It will take JOG-size input and output and scan them in either color or black and white. It will discriminate 32 colors and 16 gray levels with spot sizes that run from about 0.5 to 4 mil.

Another feature of a laser raster scanning plotter (fig. 7) is the ability to scan and plot color. Color scanning is accomplished by one laser, which is an argon-ion laser that is poisoned with krypton, giving you red, green, and blue. These can be compensated to effectively give you a white light beam, so that if you have an original that is in color or color-coded, you can actually do color pulls with laser scanning.

Peucker (Simon Fraser Univ.): If you had a 40- by 60-in plot with 800 lines/in, I calculate that you produce about 2 billion spots/hr or about 3000 spots/sec.

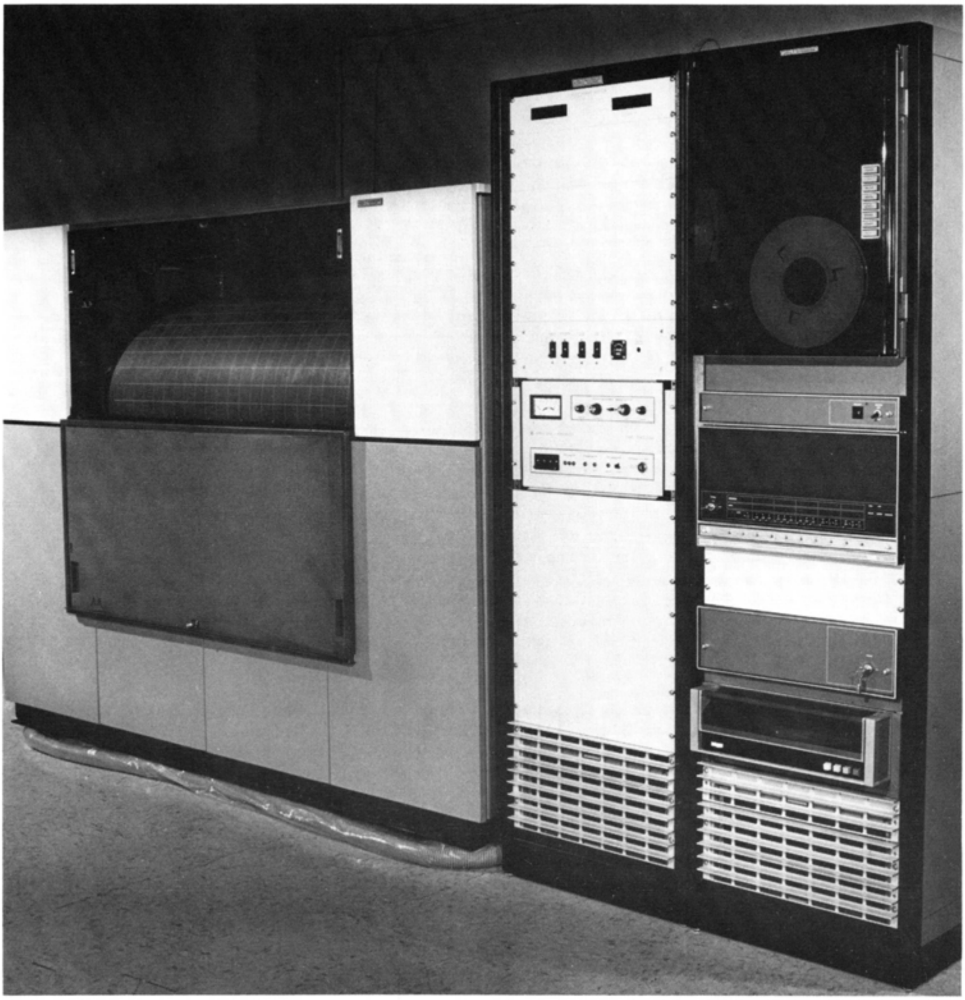


Figure 2

Raster Drum Plotter Features

- 800 Line resolution with 0.003" spot size
- 42" X 60" recording on 44" X 66" film
- Off - Line production system
- Real Time Disk - controlled computer system
- Upgrade to scanner plotter

Figure 3

SIGNIFICANT RASTER SCAN SYSTEM FACTORS

COMPACTED RASTER TAPE DATA BASE, ALL - DIGITAL MAP PRODUCTION

COLOR FEATURE SEPARATION CAPABILITY

CARTOGRAPHIC REGISTRATION & FULL RESOLUTION

FLEXIBILITY TO SCAN ARCHIVAL FLAT DOCUMENTS AND PLOT SEPARATION NEGATIVES/POSITIVES

ON LINE SOFTCOPY MERGE/EDIT/VERIFY

SCALE CHANGE LINEAR AND ANAMORPHIC FACTOR OF 2 and 1/2 + TOLERANCE SCALING

Figure 4

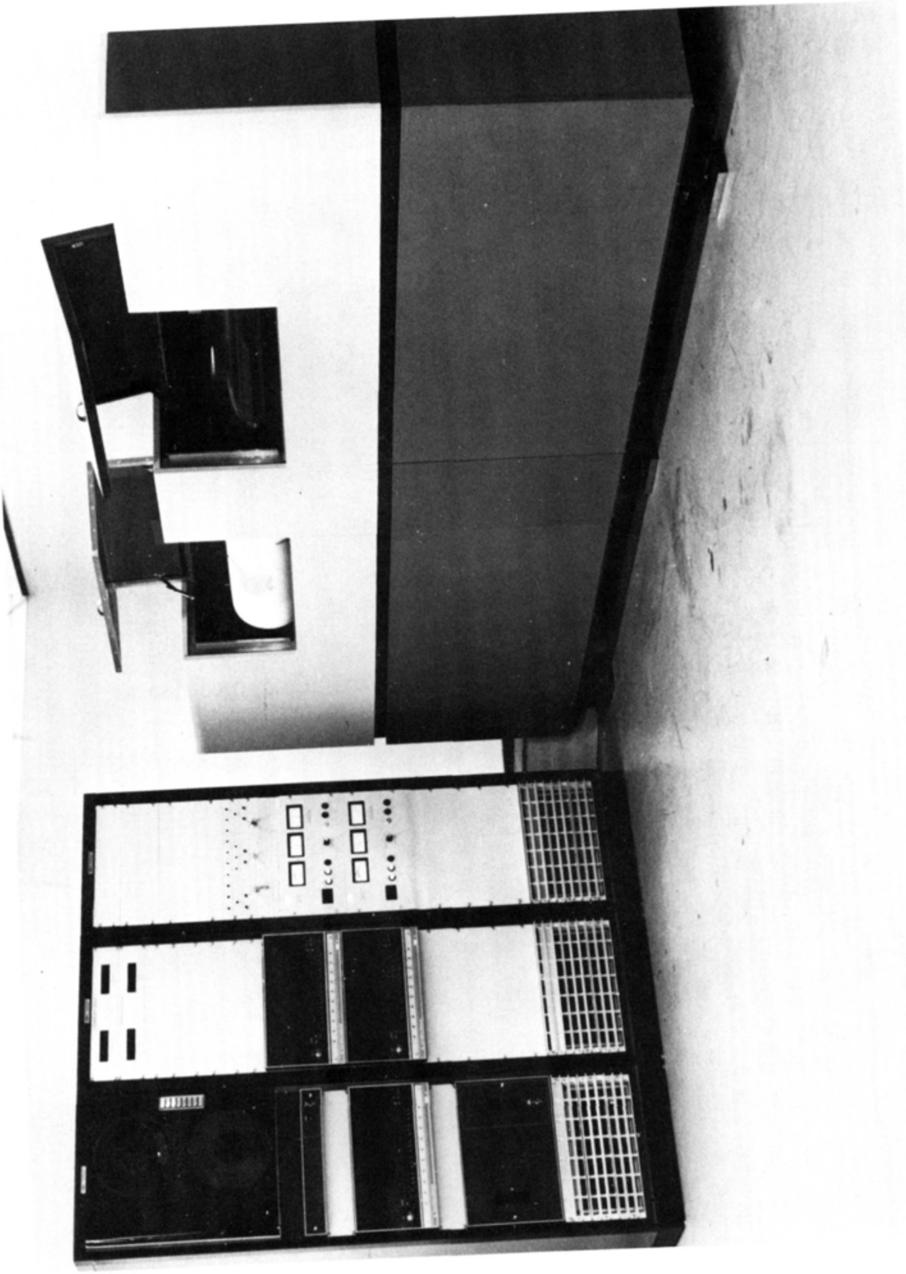


Figure 5

Scanner

- Accept color coded archival records
- Discriminate 32 colors and 16 gray levels
- Spot sizes of 0.0005, 0.0007, 0.001, 0.0013, 0.002, 0.004 inches
- Input graphic size: JOG size chart ( 24" X 32" )
- Pin registration
- Absolute position determination

Figure 6

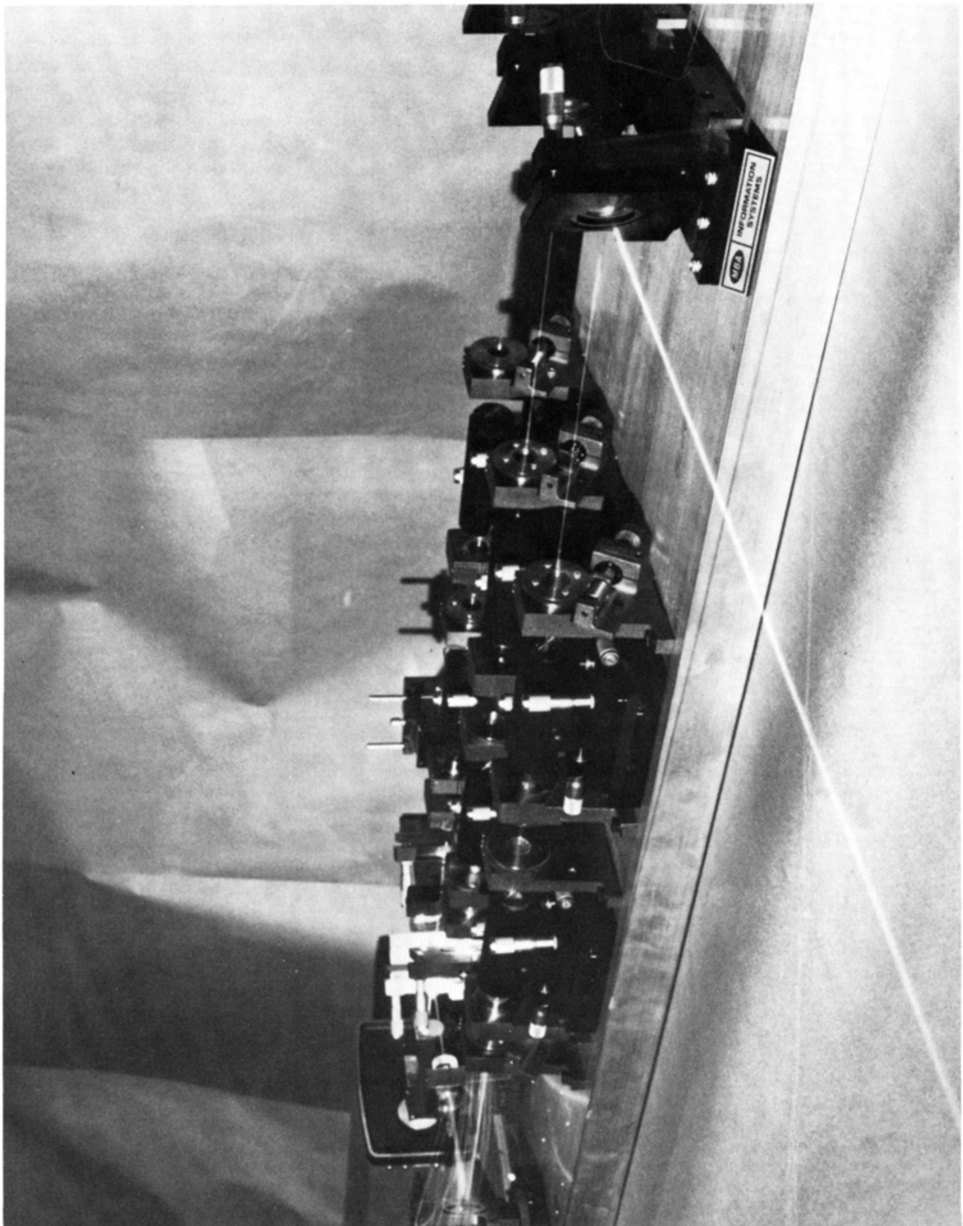



Figure 7

Healey: I think you will find that the data rates are higher; considering dead time and all the things that you are putting in there, the data rate is about 0.5 MHz.

Peucker: If I have to do that point by point without scan conversion, I could get away with the minicomputer. If I have to do scan conversion for a 40- by 60-in scan, simply to keep the data in core, I think it needs quite a beating.

Healey: It is a very large amount of data. No, you don't do that, Tom. The data is handled quite differently. Let's take a look at an individual color separation. You will find that the percentage of black area to clear area is very very low, or in the case of a large area fill the inverse may be true. If the inverse is true, we can invert this in a negative way so that we can decide which data field we are going to compress. The information is generated by the computer (360/195) as a compressed binary-image on magnetic tape, so we are only storing actual data points on tape. For example, in the final checkout for the plotter, we are going to plot every point. That is about 10 reels of 2400-in/reel magnetic tape--no way will this be done in the production operation. Data will be stored in greatly compressed binary-image form, from about 25,000 in of data to a little less that 1 roll of magnetic tape, which is approximately a 10:1 data compression.

What we do when we are going to fill the whole plot is just, for one line, do a delta-mode compression as far as our controls are concerned. For instance at position X1333 we turn on, and then we go all the way to where it is going to turn off, say X46001, and turn it off. So we are not storing all that data, all the dots between X1333 and X46001, as far as the magnetic tape is concerned.

Chrisman (Harvard Univ.): I am following on Peucker's question. You are compressing each raster line in terms of where it starts and where it stops, is that right?

Healey: That is one of the techniques that we use. There are several compression techniques that are used in this system--that is the simplest.

Chrisman: What are the others?

Healey: We also use the redundant area compression, which means that we take care of more than just one line at a time.

Chrisman: Wouldn't you get a bigger compression by doing line recognition and ignoring entirely the raster nature of your physical device? In looking at the linear nature of the actual feature that you are trying to represent, Peucker and I are trying to ask you whether you can have such a small data base if you have an actual linear feature system that you could generate whatever raster that you needed without having to worry about the physical nature of your output device.

Healey: Yes, that kind of software, I know, is in the works, but it is not here operationally today to handle that particular size format, as far as I know. We are following this very carefully. We know that a number of people are working in the area as we are. We are talking about a system that is going to go operational and start producing charts next month.

Chrisman: My problem is the feeling that if we get systems which are nailed to the floor by the bulk of data implied in a system like that, we will never be able to get out of it. A billion is a big number. I am scared; I am a little guy, you know. I use one little device. I grew up with a CalComp plotter, you know. When you start conceiving billions, I get scared.

Healey: That is one of the reasons that I prefaced my remarks with the fact that I honestly don't think the little guy (small user) is going to wind up with a large production plotter like this. The little guy doesn't have to turn out that many maps every day.

Chrisman: But I would like to have access to the data that is being developed that way. I think everybody should have access to this data, no matter whether they are small or large. I would rather have the data bases not be dependent on the device.

Healey: The data that we are getting originally is coming from a digital data base--the base that NOS has. What we are trying to do is not to go back into the big data base every time. We have small segments that we are going to update. We will take those small segments with the new data and merge them with data that we have stored on the last piece of film that was exposed on the plate. Then we will scan everything else. There is just one section in this hopper here, or similar to that, that has changed; that data would come in through any one of a number of the new systems, as far as we are concerned.

Carr: That is a good question. It raises a point that I think a lot of people overlooked when they got into raster scanning and raster plotting hardware, and that is the software to support it. Recently, in some of our work at ETL, we have tried to apply a new type of computation to raster data. We have worked with the Goodyear Aerospace Group to evaluate their unit, STARRAN, which uses associative ray techniques. We do have two representatives from Goodyear who have been working in this area. We found that we could take software programs that were requiring about 3 hr of computer time and reduce that to about 7 sec using STARRAN techniques. We are talking about handling an awful lot of data in this 7 sec. I would like you to talk to the people here from Goodyear; they may be able to answer some of your questions about handling large amounts of data in a very quick manner.

The next gentleman that I would like to present is Edward Snow from RETICON. RETICON has been involved in manufacturing microchip arrays for image scanning--self-scanning type of technology.

Snow: I feel a little bit out of place here, today. First of all, I am not sure that the device that I am going to talk about might not be more appropriate in the session on input rather than output devices. I am going to talk about a component--a semiconductor component--rather than a complete system. The component is a silicon-photodiode ray--a self-scan photodiode ray or solid-state image sensor that goes under a variety of names. These devices are integrated circuits which, in presently available types, contain up to 1024 photodiodes (individual photo sensors) together with multiplex chips, multiplex switches, and scanning circuitry, all on a single chip of silicon less than 1 inch in dimension. These devices are presently being used in facsimile systems in optical character recognition (OCR) as well as in size, position, industrial inspection applications; they certainly have applications, I am sure, in cartography. I am not an expert in cartography, however, so I am going to describe the device and leave the applications more or less up to you.

(Slide) (Editor's note: Slides not available for publication.) This is the type of device we are talking about. This particular one has 1000 photodiodes in a line down the center of the silicon chip. These are on 1-mil centers. The total package is about 1.5 by 4 in. In addition to the photodiodes there are multiplex switches and shift-register scanning circuitry built on to the integrated circuit chip.

(Slide) Here we have represented schematically the 1- by 1-mil photodiode, a capacitor, a multiplex switch which is an MOS transistor, and a scanning ciruit. In operation, the photodiode senses light and converts it to electrical charges which are stored on this capacitor. As we scan through the shift register, these charges are read out in sequence through the switches and onto an output line. We get a sequence of charged pulses, each one proportional to light intensity of the corresponding cell.

(Slide) Here are a few of these devices, showing that with the same basic design these devices can be made in any length, from small ones (this one is 256 elements) available down to 64 elements up to 1024 elements, which are commonly used for OCR applications. The large ones can be used for full-page width facsimile. We can scan a full page of information in approximately 1 sec with a device like this.

In the background is shown some of the topology of the silicon chip. You see the line of photo sensors (each one being a little area like this), the storage capacitor on which charges are integrated, and a multiplex switch through which it is read out. One of the switch register circuits is shown on this side. These devices here are line scanners or linear arrays. There are also matrix arrays available.

(Slide) Here we show a schematic of these devices. They are essentially the same thing, except we have two switches--one for x and one for y addressing--so that they can be raster scanned.

(Slide) Here is a photograph of the matrix array of one of these devices.

(Slide) Here we see a 2-dimensional array having 50 by 50 photocells with 2 shift-registers for scanning, one on each edge of the chip. The shift registers are in the background. There are 2 switches that you can't make out unless you know what you are looking for on each cell. This device is on 0.4-mil centers in each dimension.

(Slide) This shows the kind of output one gets from these devices. This is simply scanning as an image sensor across a black-to-white transition on a piece of paper. The paper is imaged onto the array;

there is a black/white edge right here. We see a low output from the diodes here and a fairly abruptly changing output to the high level right here. In fact, one can make a black/white transition in a single diode space if the optics are good enough. This corresponds to 1 mil in the common variety devices. These are the recharge pulses coming out of the device as each of those charge pulses is sampled in sequence. If we go through an integrating sample and hold circuit, then we get an output array form like this. The devices are capable of dynamic ranges up to about 1000:1 or even better in some applications.

(Slide) This shows some of the progress in the state of the art. In devices of a few years ago, we were able to make about 32 diodes in a row. Here is a picture of a horse that was taken with this device. The device is scanned in this dimension electronically, and there is a mechanical scan in the other dimension which you can't quite make out in the picture. If we go to 64 elements, you can see that maybe it is a mule. Finally, by the time we get up to 512 elements, we are making very good duplication of the original. The dynamic range in this picture is limited by the CRT that the picture is displayed on, not the image sensor. These devices are now available up to 1024 elements, and shortly they will be available up to 2000 elements.

(Slide) In this last slide, I show some of the same pictures. This is just displayed on a line plotter. We have actually threshholded the output instead of using the analog form to display black/white information, again going from a poor-resolution, 32-element device up to a 512-element device.

I would like to summarize by mentioning some of the advantages of this type of device. The obvious attributes are the small size, weight, and low-voltage. Another is the almost perfect geometric accuracy as compared to CRT devices or vidicon cameras as a pickup device. This device has the diodes on essentially perfectly defined center-to-center spacings. Since it is scanned electronically rather than by electron beam, one knows the exact position of each point of information. The devices are read out by a digital clock which controls the scan rate. These clock rates can be set arbitrarily up to about 10 MHz, diode-to-diode sample rate. Since it is a clock system, it makes it very compatible with computer-processing data.

As far as the state of the art is concerned, linear arrays can be used for full-page scanning, that is, for digitizing information with a full-page scan. We have up to 1000-element devices, and 2000-element devices will be along shortly. Matrix arrays of 50 by 50 elements are available, and 100 by 100 or 200 by 200 will be available before too long. This technology is very, very flexible as far as the nature of the scan. I mentioned line scan devices and 2-dimensional raster scan devices. Devices that scan in a circle have been built also. The geometrical format of this type of device is almost completely arbitrary. I think that we used the 50- by 50-element chip that RETICON built for producing images on a TV set, and we have that on display. We are seeing technology come along to the point where images are being produced from small chips no bigger than the tip of your finger.

At this time, I would like to introduce Pat Grosso from Image Graphics, Inc., who is going to talk about electron beam technology. Pat was involved in the ERTS program from the very beginning--reducing some of these digital data being transmitted back to picture form. He has worked as a manager of CBS Laboratories and was involved in the NASA installation in the Goddard Space Flight Center, as well as one in South America. He has published several papers and is currently the new president of Image Graphics, Inc.

Grosso: Electron beam recorders (EBR) have been selected as the hard-copy output devices for a variety of high-resolution applications--for imagery, graphics, and data. This includes the NASA Earth Resources Technology Satellite (ERTS) program that we have heard so much about in the U.S., Canada, and Brazil. There is an extensive display of ERTS images in the lobby, and you will be getting samples of some of the output products.

Today, I would like to talk about the use of EBR's as hard-copy output devices not only for imagery, but also point-by-point plotting for automated cartography. The high resolution and computer-control capability of electron beam recording enabled the geometric and radiometric errors caused by the satellite and the sensors to be corrected to within mapping accuracies, online during recording. Colvocoresses from USGS has written numerous papers on the subject; in fact a recent paper is being handed out in the lobby. This recording ability, cost-effectively, increases the image throughput of the overall ERTS system by decreasing the extensive computer processing time, which is normally required to provide a suitable data base for other types of raster and optical-mechanical recording systems where the beam cannot be programed.

EBR's have recently been adapted for automated cartographic applications. EBR systems are now capable of generating map separations on film from computer-processed data bases. The film is subsequently enlarged to make printing plates for conventional printing presses, from which full-scale color composite maps are produced.

Figure 1 shows such a system developed by CBS Laboratories under contract to the Automated Cartography Branch at Ft. Belvoir, directed by Howard Carr. Map and character data bases are stored on computer-generated, digital magnetic tapes. The tapes are read and the data transferred to the core memory of a PDP-11 minicomputer. For point-by-point plotting, such as a contour sheet, the minicomputer computes the positional and vector information from the raw digital data and transfers these signals into a vector generator. The vector generator converts the digital signals to analog signals which accurately position a 3-μm-diameter electron beam over a 32-k by 32-k address matrix. During plotting, the line width can be varied automatically by software instructions and hardware control.

In addition to being able to plot point-by-point in a very accurate fashion, the EBR system also can produce graphic-arts-quality characters, such as are used on a names data sheet. Digital representations of characters or symbols are read into the 1.2-million work disk which is used as a character library. Over 40 fonts of 100 characters can be stored on each disk. The disk controller is capable of controlling 3 disks, so the system is capable of calling up 16,000

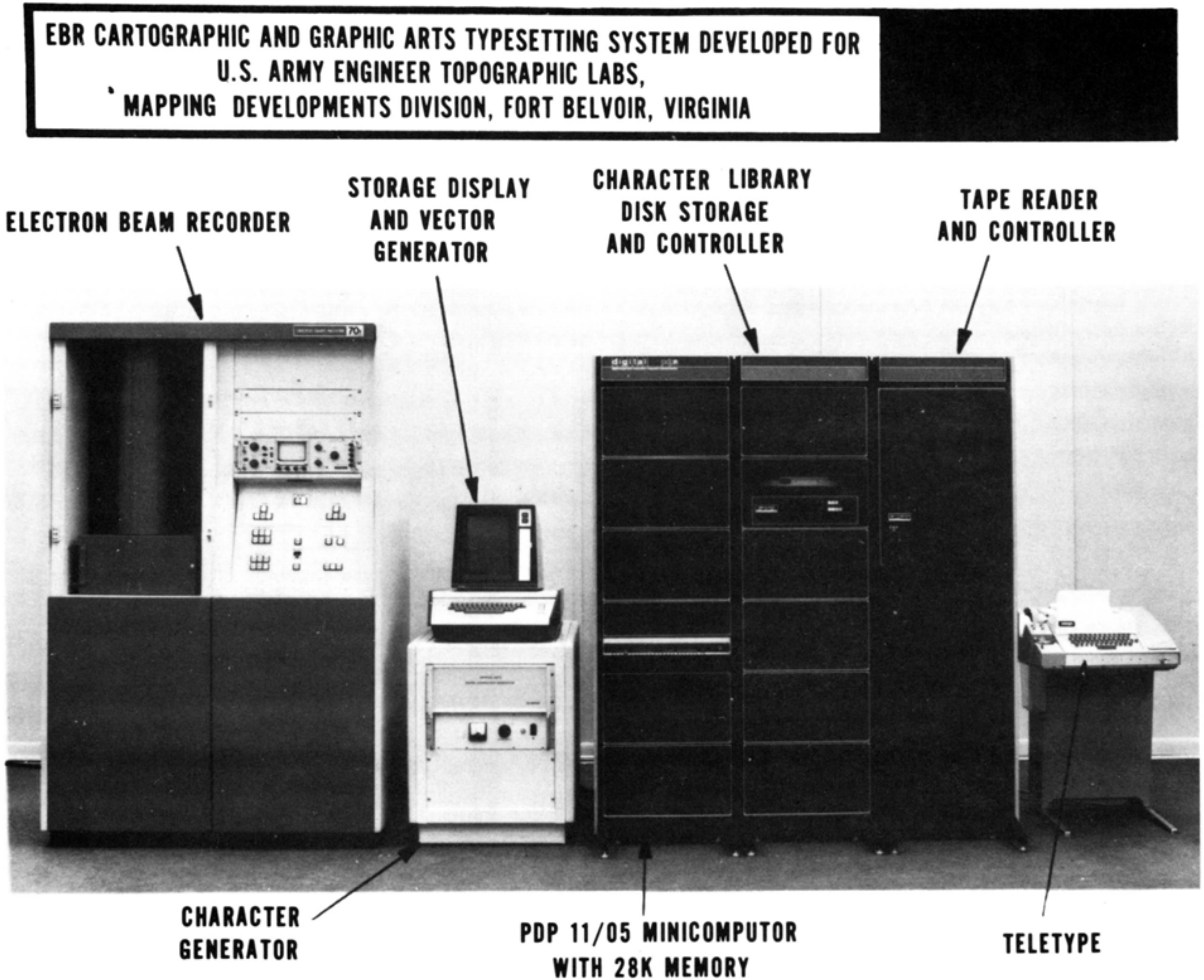

EBR CARTOGRAPHIC AND GRAPHIC ARTS TYPESETTING SYSTEM DEVELOPED FOR
U.S. ARMY ENGINEER TOPOGRAPHIC LABS,
MAPPING DEVELOPMENTS DIVISION, FORT BELVOIR, VIRGINIA
ELECTRON BEAM RECORDER
STORAGE DISPLAY AND VECTOR GENERATOR
CHARACTER LIBRARY DISK STORAGE AND CONTROLLER
TAPE READER AND CONTROLLER
CHARACTER GENERATOR
PDP 11/05 MINICOMPUTOR WITH 28K MEMORY
TELETYPE

Figure 1

characters in a random fashion at any one time. Characters are generated using a sub-raster from the digital character generator.

The EBR records directly on film in vacuum and thereby eliminates all problems associated with cathode ray tubes with regard to resolution and brightness losses caused by lens and phosphor coatings. A very small spot size can be produced for very high-resolution applications. Using electron sensitive film, which is a very fine-grain silver halide emulsion like a spectrographic plate, you obtain extremely good definition of characters or map line work that you record. The film is wet-processed in the conventional manner, and images can be either positive or negative, depending upon the processing or the type of film that is used. Recently, electron-sensitive films which require no processing whatsoever have also been made available on an experimental basis by Eastman Kodak. These should be of importance for proofing and certain cartographic applications.

Figure 2 is an enlarged section of a typical contour sheet plotted with a 3-μm beam. This recording was actually made from two map-separate data bases. Even under very high magnification, one cannot distinguish the joins between the two separates. Copies of the original recordings and some of the prints are on a display here.

Figure 3 shows some enlargements of characters that were generated with this system. The characters are graphic arts quality and were recorded at 48X reduction. Even under very high magnification, you can see the graphic arts quality is still retained. Sample recordings of graphic-arts-quality characters on 70-mm and 5-in formats are available for viewing.

The EBR high-resolution beam and the fine-grain emulsion of the electro-sensitive film enable enlargements of over 10 times to full map scales. Some of these full-scale maps are also on display. These film chips can be readily utilized in production of maps and other cartographic products.

Figure 4 is a flow chart that indicates how one might use the film chips in map production. Map separates (70-mm) generated from digital data bases through the EBR cartographic system are used as color separates; these can be enlarged to produce negatives from which printing plates can be made. The printing plates are then run through a conventional multicolor press to generate 20- by 30-in to 40- by 60-in maps. The micromap film chips can also be used directly to expose full-size diazo printing plates with a UV platemaker. The printing plates made directly from micromaps are used to print 20- by 30-in color composite maps using a conventional color press.

Figure 5 shows the use of the EBR system for recording at full scale. This capability would be useful for preparing and revising aviation flight charts. Here the different separations for airport patterns, approach procedures, and names data would be recorded at full scale on 5- by 8-in film and either contact printed individually or combined on enlarged composite printing plates with as many as 32 "pages-up." The printing plates would be then run through a conventional press. The flight charts are printed, cut, and collated; the final product would be a complete flight information handbook. This particular

SECTIONAL ENLARGEMENT OF
A TYPICAL CONTOUR SHEET MADE FROM TWO MICROMAP SEPARATIONS

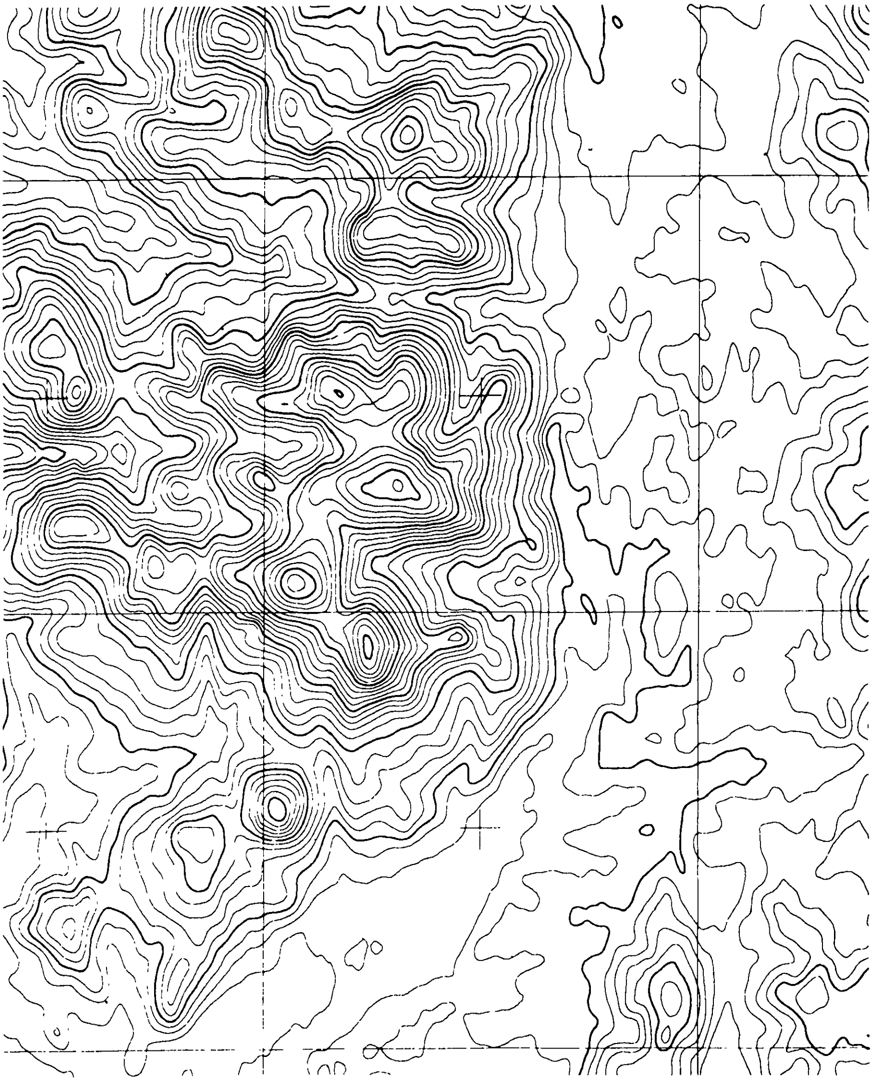


Figure 2

**ENLARGEMENT OF 48X MICROFICHE
WITH GRAPHIC ARTS QUALITY CHARACTERS**

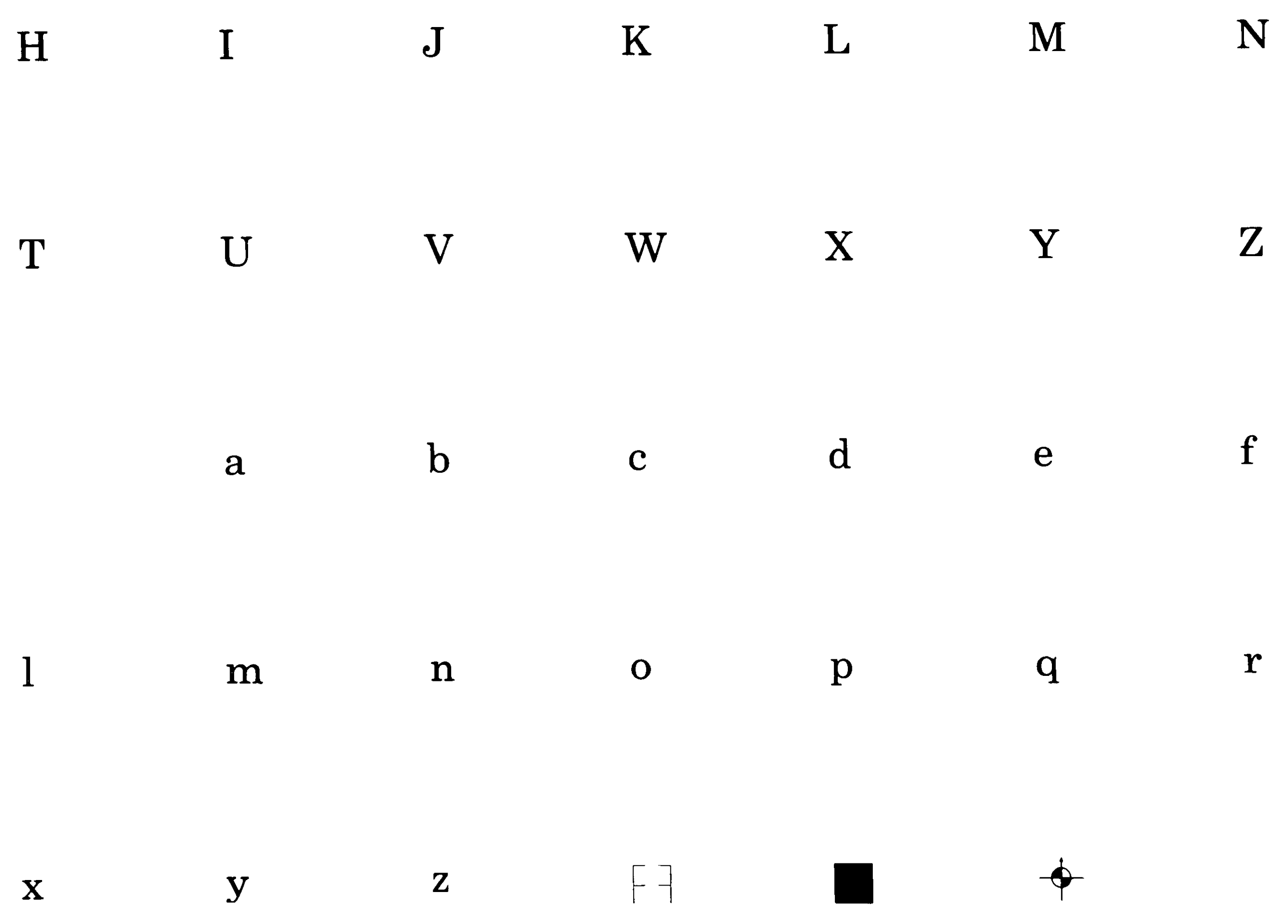



Figure 3

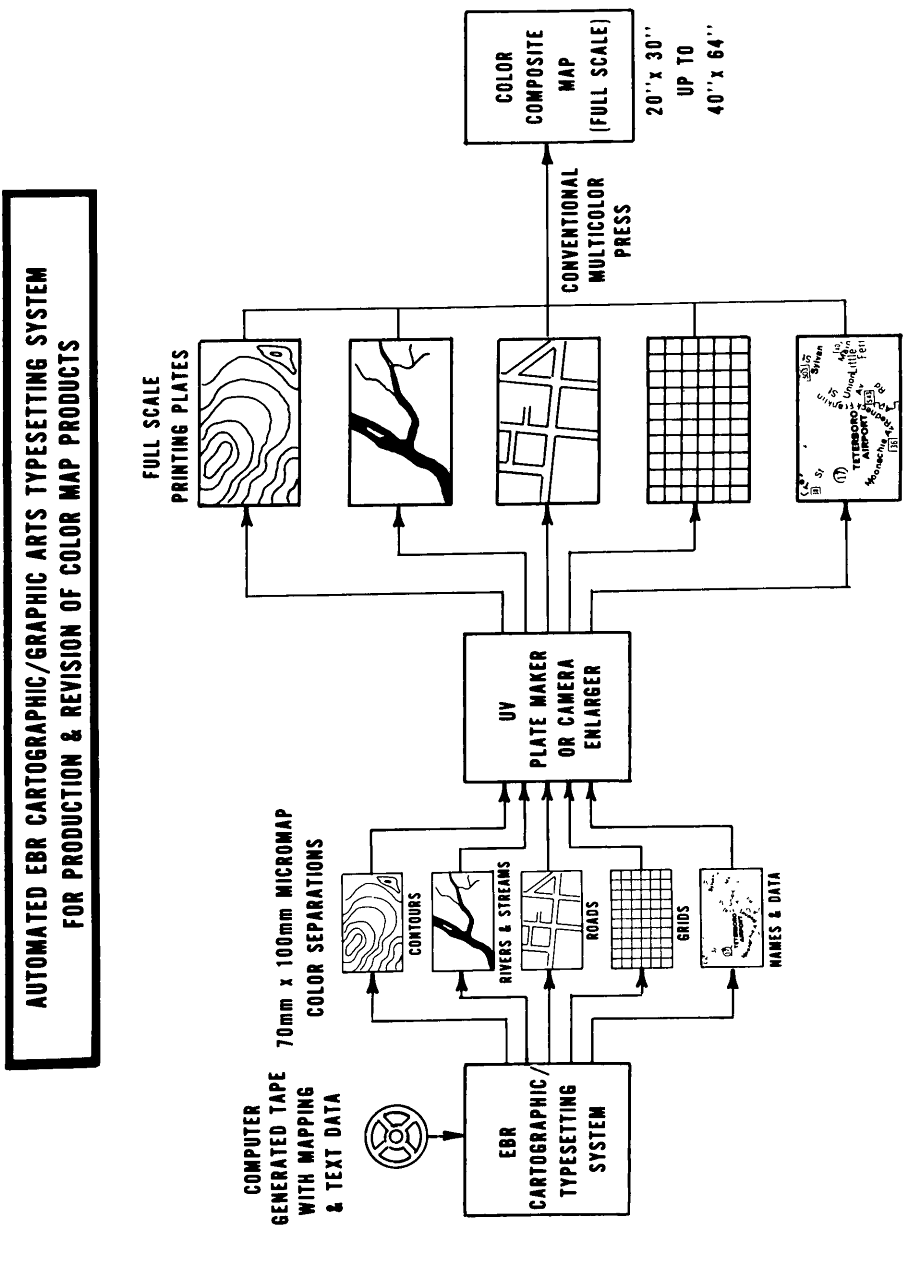

AUTOMATED EBR CARTOGRAPHIC/GRAPHIC ARTS TYPESETTING SYSTEM
FOR PRODUCTION & REVISION OF COLOR MAP PRODUCTS
COMPUTER GENERATED TAPE WITH MAPPING & TEXT DATA
EBR CARTOGRAPHIC/ TYPESETTING SYSTEM
70mm x 100mm MICROMAP COLOR SEPARATIONS
CONTOURS
RIVERS & STREAMS
ROADS
GRIDS
NAMES & DATA
UV PLATE MAKER OR CAMERA ENLARGER
FULL SCALE PRINTING PLATES
CONVENTIONAL MULTICOLOR PRESS
COLOR COMPOSITE MAP (FULL SCALE)
20''x 30'' UP TO 40''x 64''

Figure 4

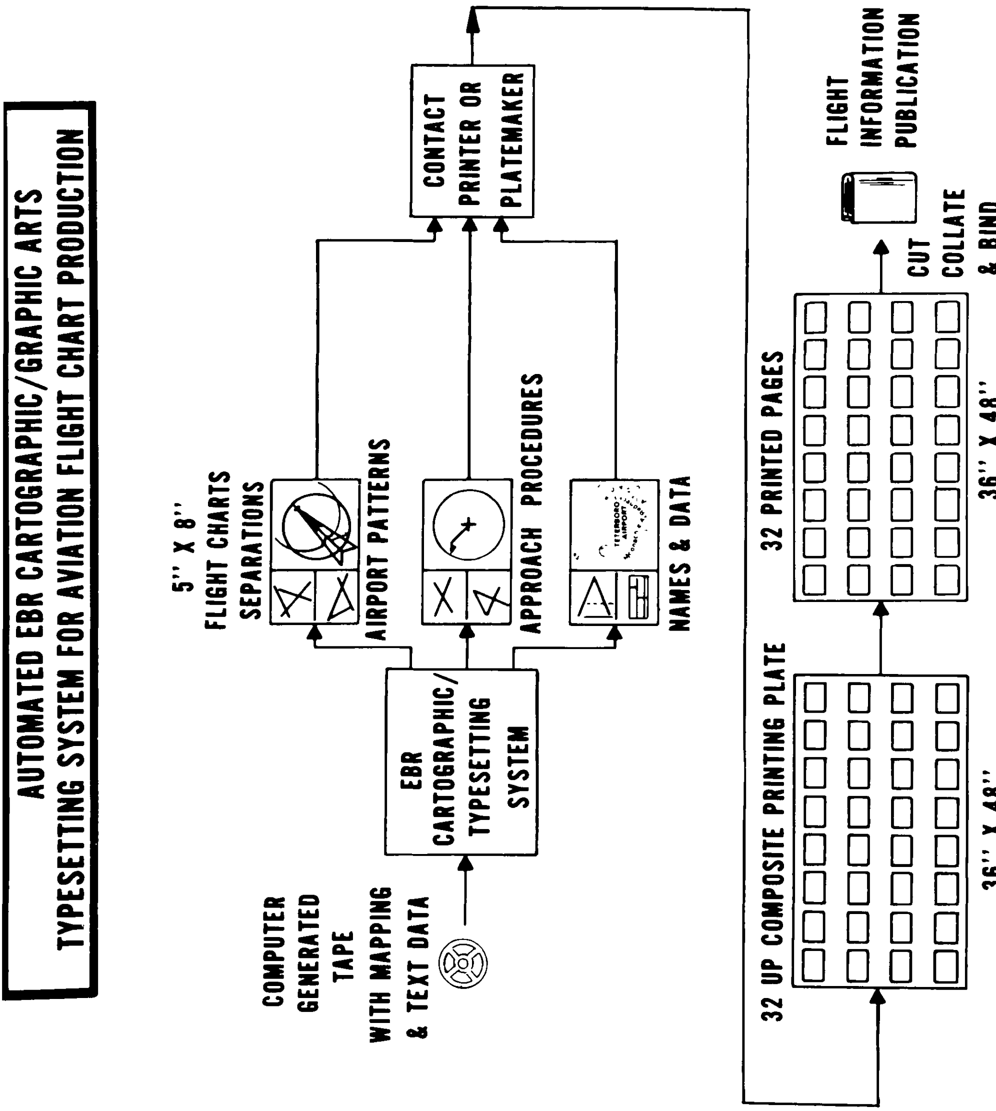

AUTOMATED EBR CARTOGRAPHIC/GRAPHIC ARTS
TYPESETTING SYSTEM FOR AVIATION FLIGHT CHART PRODUCTION
COMPUTER GENERATED TAPE WITH MAPPING & TEXT DATA
EBR CARTOGRAPHIC/ TYPESETTING SYSTEM
5'' X 8'' FLIGHT CHARTS SEPARATIONS
AIRPORT PATTERNS
APPROACH PROCEDURES
NAMES & DATA
CONTACT PRINTER OR PLATEMAKER
32 UP COMPOSITE PRINTING PLATE
36'' X 48''
32 PRINTED PAGES
36'' X 48''
CUT COLLATE & BIND
FLIGHT INFORMATION PUBLICATION

Figure 5

system has not been built, but the capability of recording to the accuracies and sizes required is in the basic EBR cartographic system. These map production techniques would be cost-effective operational procedures, which can be efficiently used to increase product output. In addition, combining the EBR cartographic capability with the ability to record high-quality, precision imagery from satellites such as ERTS will enable the automated production of new map products.

Figure 6 is a sectional view of a USGS "pictomap," where they have taken an ERTS image and manually superimposed a map overlay. By using a combination of EBR cartographic plotting and raster image recording as used on ERTS, you have the possibility of directly generating a new type of product. This would mean always having current information. ERTS images have shown us that land forms and water forms are changing continuously and make our mapping data outdated quickly.

You will be getting a sample image map in your registration packet. The EBR recording system offers the potential to produce this type of map in an automated fashion. I hope the sample will stimulate your interest in the use of a combination of ERTS imagery or aerial photography and cartographic point-by-point plotting.

Some performance capabilities of such a recording system are shown in figure 7. For cartographic applications in the vector plotting mode one can record variable line widths starting with a 3-μm spot; these recordings can be enlarged up to 30 times. As opposed to the gentlemen who said that sometimes too much resolution is just as much of a problem as no resolution, I think that when you have the resolution capability you certainly want to use it. For example, when you are drawing a 1-mil-wide line, you should not draw the line with a 1-mil spot; you should draw several 0.2 mil lines. This will produce the best edge sharpness. If the image quality warrants it, resolution should be the best possible, even at the expense of speed. Writing speed in this particular case was 125,000 points/sec, and the beam addressing was 32 k by 32 k. Again, beam diameter was 3 μm and can be enlarged well up to several mils, if necessary.

In addition to the vector mode, the EBR can be used in a raster plotting mode to generate continuous-tone imagery with at least 64 gray shades. The limitation is the film, not the recording system. EBR's have actually been built to record 256 discrete levels, but these gray levels are not distinguishable on film. The raster plotting mode will enable using the EBR for black-and-white line art with conventional software packages that are available, at writing sppeds of 250,000 points/sec and even faster if it were required. EBR's have been used in applications with band widths up to hundreds of megahertz.

The resolution in the EBR raster mode has none of the limitations of the cathode ray tube. Resolutions of 10 k to 15 k TV lines at 50-percent response on 70-mm format have been recorded. This performance level is very common for the EBR. In larger formats of 5 in, over 20,000 elements can be obtained. The EBR system can also have an electronic halftone capability, and we feel that 65 to 133 lines/in could be obtained. There is a wide range of film formats that can be used--16 mm, 35 mm, 70 mm, 105 mm, 5 in, 9 in, and the standard microfiche.

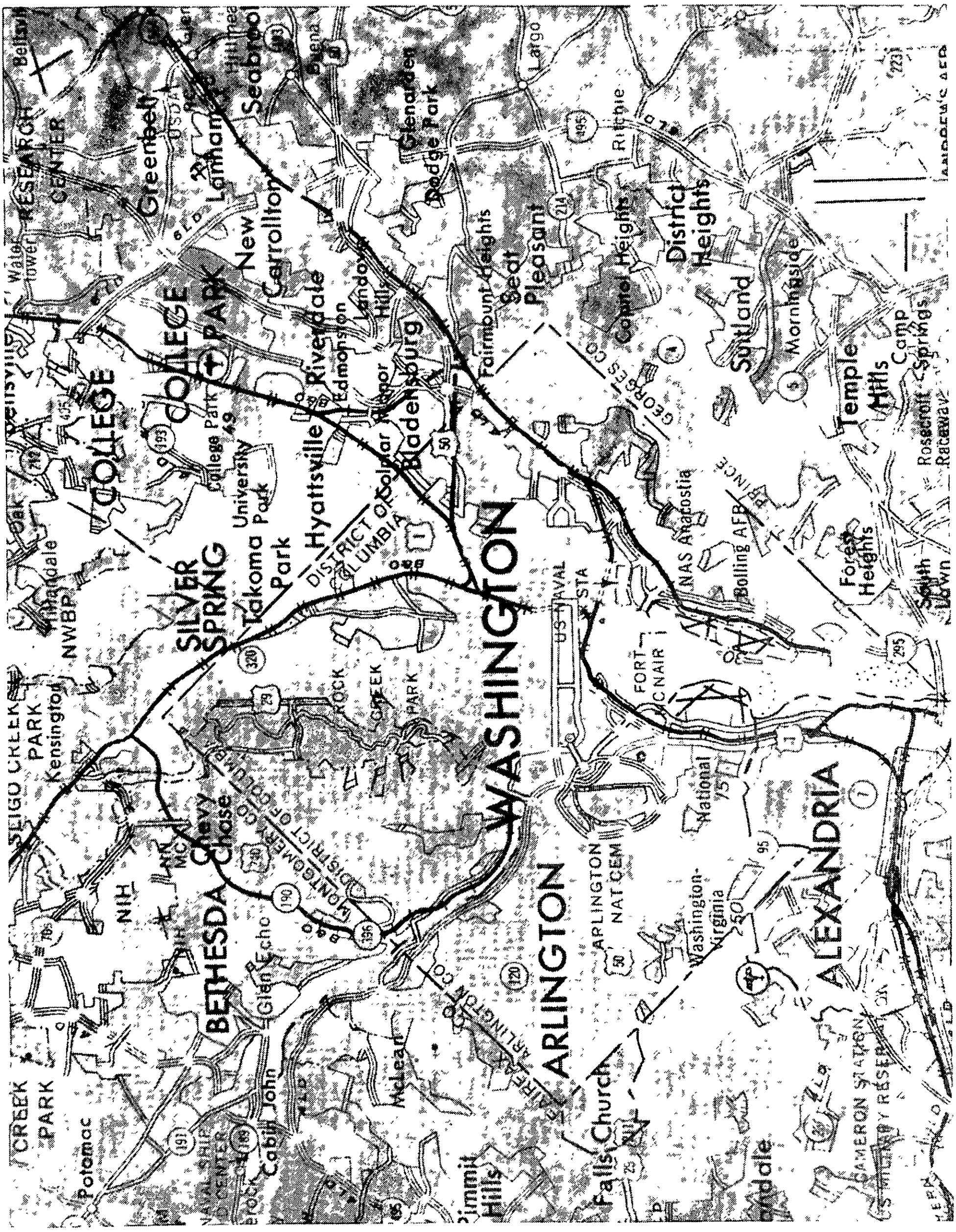

WASHINGTON
ARLINGTON
ALEXANDRIA
BETHESDA
SILVER SPRING
COLLEGE PARK
Takoma Park
Hyattsville
Riverdale
Bladensburg
Greenbelt
New Carrollton
Seat Pleasant
District Heights
Suitland
Temple Hills
Camp Springs
Forest Heights
Chevy Chase
Falls Church
McLean
Potomac
Kensington
Glen Echo
NAS Anacostia
Bolling AFB
FORT McNAIR
National
ARLINGTON NAT CEM
DISTRICT OF COLUMBIA
ROCK CREEK PARK
University Park
Edmonston
Capitol Heights
Fairmount Heights
Landover Hills
Morningside
Lanham
Seabrook
Glenarden
Dodge Park
Ritchie
Largo
Cabin John
NIH
Washington-Virginia

Figure 6

# TYPICAL EBR AUTOMATED CARTOGRAPHIC AND GRAPHIC ARTS TYPESETTING SYSTEM PERFORMANCE CAPABILITY

## CARTOGRAPHIC/BUSINESS GRAPHICS

VECTOR PLOTTING MODE

a. Variable line widths - starting with 3 microns (1/8 mil X 30X = 4 mil line)

b. Writing speed - 125,000 points/sec

c. Beam Addressing - 32K x 32K

d. Resolution -3μ beam diameter spot

RASTER PLOTTING MODE

a. Continuous Tone Images with 64 Gray Shades

b. Black and White Line Art

c. Writing speed - 250,000 points/sec, faster speeds available

d. Resolution -8,000 to 15,000 TVL; 50% response on 70mm format to over 20,000 elements for larger formats

HALFTONE CAPABILITY

a. 65 - 133 screens/inch available

FILM FORMATS AVAILABLE

16mm, 70mm, 105mm, 5", 9", microfiche

Figure 7

Figure 8 shows performance of the graphic-arts character generation. You have great flexibility of point size--4 to 36 and larger--and you have random access by using the disk library. Characters can be rotated 360 degrees in 1-degree increments. Character writing speeds for graphic arts quality are 1360 characters/sec for 5 to 8 points; faster rates can be achieved if you are willing to give up a little bit of quality. The reason that one can use various point sizes and fonts and intermix them is the EBR automatic exposure control. Symbols may also be stored on the digital disk. Recordings of characters at 24X, 48X, and 96X reductions have been made for microfiche applications which still retain high graphic arts quality. The EBR is a new, versatile tool that has a place in automated cartography.

Wohlmut: Research and development efforts in the previous year have brought to the prototype stage a plotting device capable of writing on 5- by 5-ft film, and it is currently being modified for digitizing capability. Additional work in the field of video and digital storage on film has brought two other devices to the prototype stage--a film disk system capable of $10^{10}$-bit storage and a roll film system capable of $10^{15}$-bit storage. Each of these devices will be described, as well as pertinent current research and development.

Two types of high-density digital storage devices are under development at i/o Metrics. The LASCO device itself is capable of ultra-high storage of digital and/or visual information, but with relatively slow access. The video disk, first developed as an entertainment medium, has lower capability but fast access and low cost. Both devices are based on film storage of information and are part of the LASCO system (fig. 1).

LASCO may be used to record digital or graphic information on film in the plot mode and read it back in the digitizing mode. Its current capacity is conservatively in excess of $10^{15}$ bits of digital information. Table 1 shows the operating characteristics. The device operates

Table 1.--LASCO operating characteristics.

| | |
|---|---|
| Format | Data frames $(105\ mm)^2$ on 105-mm roll film |
| Film load | 3 rolls @ 660 m/roll, or 2000 m total |
| Maximum film slew rate | 7 m/sec |
| Average frame access time | 60 sec |
| Average access time at a fixed frame | 25 msec |
| Data bit size | $(10\ \mu m)^2$ |
| Distinguishable gray levels | 8 |
| Data record/retrieval rate at a fixed frame | 600 k bits/sec |
| Total nonredundant data store | 330 M bits/frame; 6.3 T bits/film load |

## GRAPHIC ARTS CHARACTER GENERATION

A. POINT SIZES

4 - 36 points, larger sizes available

B. CHARACTER ROTATION

0 - 359 in one degree increments

C. CHARACTER WRITING SPEED

(Up to 10 times faster speeds available at lower character resolution)

| | |
|---|---|
| 5 points - 8 points | 1360 characters/sec |
| 10 points - 18 points | 450 characters/sec |
| 36 points | 225 characters/sec |

D. CHARACTER FONT STORAGE

Approximately forty 18 point fonts on a 1.2 million word disk

E. AUTOMATIC EXPOSURE CONTROL

All point sizes can be intermixed, all fonts can be intermixed

F. CHARACTER DIGITIZATION AT HIGHEST RESOLUTION

1664 points per inch in the verticle direction

832 points in the horizontal direction

G. MICROFICHE REDUCTION RATIO

24X, 48X, 96X and greater for special applications

Figure 8

under computer control, holding up to 6000 ft of 105-mm film and recording and playing back with a 10-μm or smaller laser probe. Visual information (e.g., microfiche) may be interspersed with digital information. Editing may be performed on any 105-mm frame. All display facilities of the digitizer are accessible thus permitting digital input or output on any peripheral, visual display on a large screen or closed circuit TV, and diagnostic information on oscilloscopes and storage tubes. Operator intervention is possible at all times to override automatic file transport, modify data, or inspect visual data.

The film-based video disk can store in excess of $10^{10}$ bits. It is interfaced through a PDP-11 board to other computers. The PDP-11 handles the i/o and servo controls for accessing the disk, serving as a controller for this device. Operating characteristics are shown in table 2.

Table 2.--Video disk operating characteristics.

| | |
|---|---|
| Format | 32 cm diameter disk, written 5 to 15.5 cm radius |
| Track spacing, center-to-center | 2.0 μm |
| Rotation rate | 1800 rpm |
| Smallest data bit size | 2.0 μm |
| Distinguishable gray levels | 8 |
| Data recording/retrieval rate | 14 M bits/sec |
| Total nonredundant data store | 19 G bits/disk |
| Access time | 30 ms |
| Readout | Incandescent lamp |

In increasing order of sophistication, there are four ways to encode the signal.

1. As little pictures on the disk. This approach has been used (on strip film) numerous times and uses the dynamic range of the film to maximum advantage. It is an inherently clumsy format for disk applications.

2. As an analog of the NTSC signal. This approach has also been tried numerous times. Figure 1 shows a portion of a video disk written in the analog mode at the Stanford Research Institute a decade ago. The track spacing is 6 μm; note the significant grain structure that was present in what was then the finest grain, commercially available emulsion. Figure 2 is a high contrast photograph of an i/o Metrics film disk with an 8-μm track spacing. The tracks are several micrometers wide; the video signal recorded here was the standard multiburst with temporal frequencies of 0.5 to 4.2 MHz. The corresponding spatial frequencies are

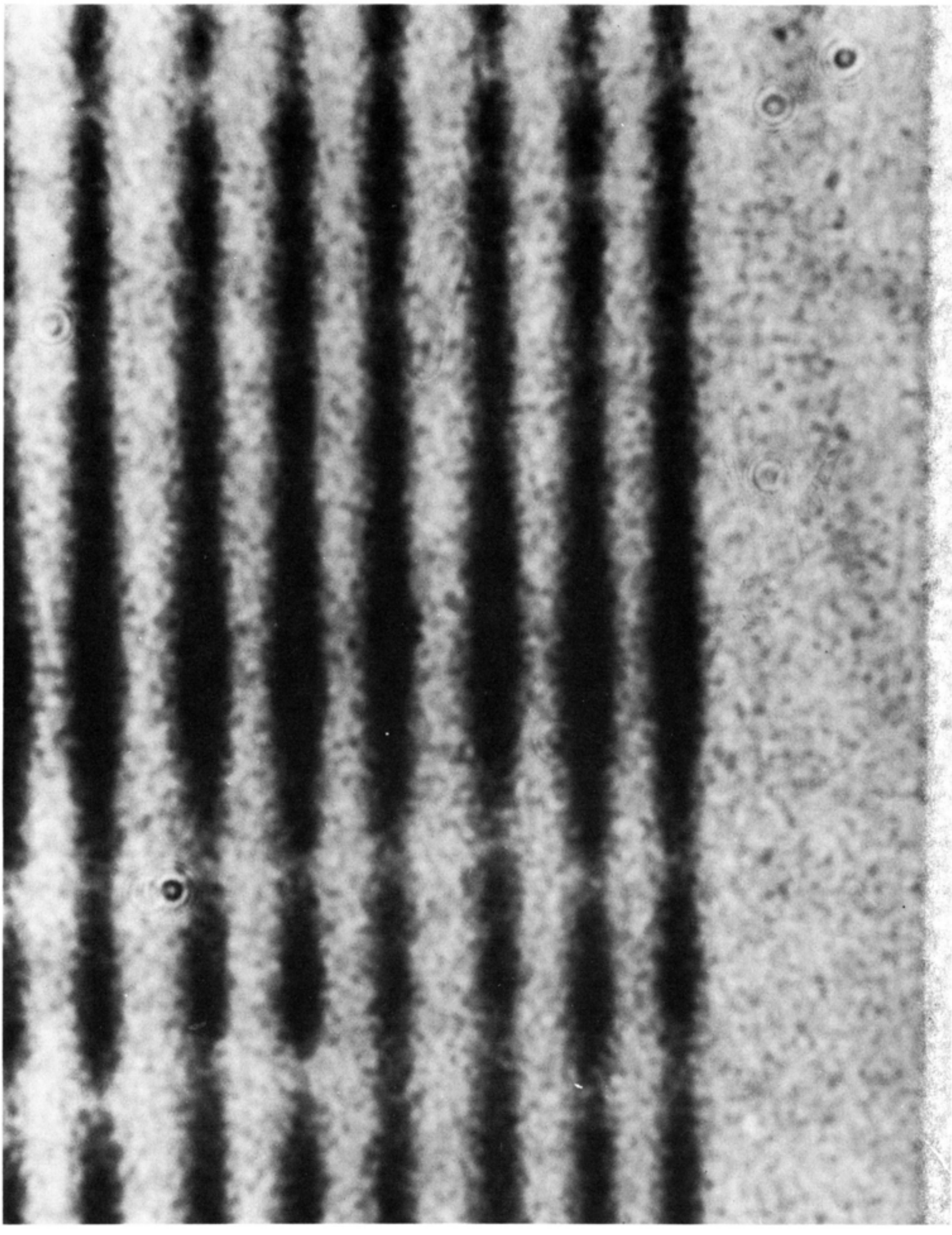


Figure 1

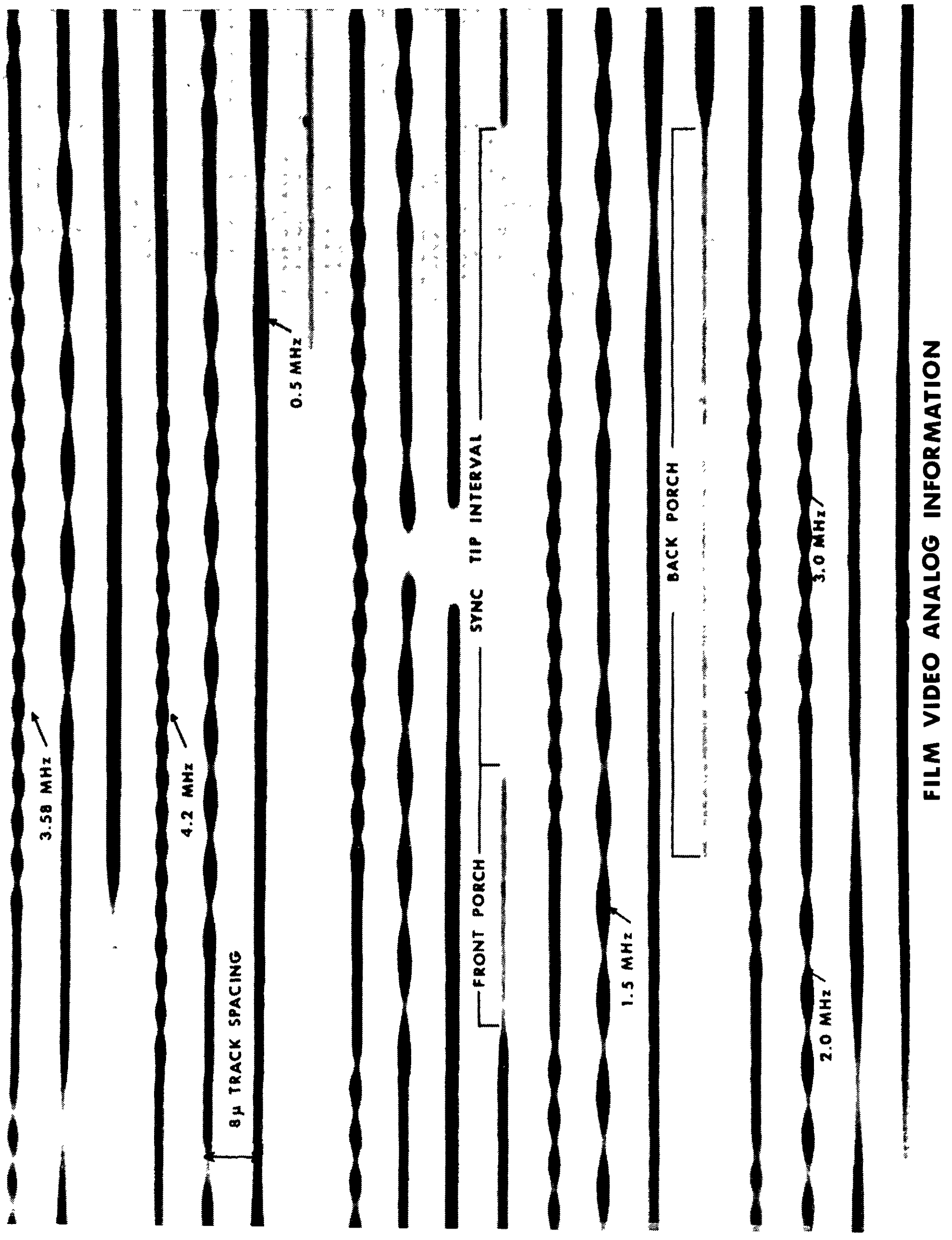

3.58 MHz
4.2 MHz
8μ TRACK SPACING
0.5 MHz
FRONT PORCH
SYNC TIP INTERVAL
BACK PORCH
1.5 MHz
2.0 MHz
3.0 MHz
FILM VIDEO ANALOG INFORMATION

Figure 2

0.025 cycles/$\mu$m and 0.21 cycles/$\mu$m. These frequencies encompass the required frequency spectrum needed for recording in the analog mode.

3. As a pulse encoded modulation of the NTSC signal. The most common pulse encoding technique is the frequency modulation mode, which is used in recording on magnetic tape. We have experimented with recording FM signals on film; figure 3 shows the same multiburst signal as recorded in the FM mode. The FM bandpass was 1.2 to 3.8 MHz--appropriate for black-and-white (luminance only) recording. Three other laboratories are currently developing optically read video disk systems with an encoded FM signal. These companies (Phillips, Zenith, and MCA) use a pressed plastic disk rather than a film disk. For comparison, figure 4 shows a segment of such a disk. Here the FM signal varies from about 6 to 9 MHz, with each pit several microns long and precisely one-half a micron deep. The two disks look very similar--these photos were made in our laboratory through the same microscope and under similar conditions.

4. As a Fourier transform (hologram) of the original picture. From some aspects, this is a very attractive way to encode the signal on film. The transformed image is insensitive to shifts in position and to translations along the detector axis. But again this is a highly cumbersome format for disk applications.

The comparative advantages and drawbacks of these four methods could be examined in great detail, but it is sufficient here to note that only the analog and the pulse coded techniques offer real promise at this time for disk applications. The transform techniques will eventually be of major interest, but for now they require diffraction limited optics and data stores of a quality difficult to maintain in the desired applications.

Of the two techniques, analog and FM, the analog signal is certainly the simplest in terms of the electronics required in recording and playback. The analog mode requires approximately one-half the bandpass of FM recordings; the latter technique, with its double bandwidth, is usually considered to have a better immunity to typical wideband video noise and to media and playback induced noise. However fingerprints, scratches, and other anomalies introduced in handling the video disk are not of this type, and we have found pulse encoding techniques become disadvantageous with respect to these latter types of noise. There is another advantage of the analog signal--it works very much like a standard projector: when the picture on the television screen is out of focus, the playback lens needs focusing; when the picture is too bright, the lamp needs to be turned down; when the picture is upside down, the disk is upside down; and so forth.

The actual apparatus which is used in a given video recording application depends on which of these encoding methods is chosen. When recording in the analog mode, a relatively straightforward hardware configuration may be used. Figure 5 shows our typical laboratory hardware. The laser beam is delivered to the acousto-optical modulator which introduces the video signal as an intensity modulation. The film disk is servo-controlled to rotate at the video framing rate; the light beam is delivered to the film surface by a simple microscope objective which is translated radially to write the spiral track of some 30 miles in length on a 40-min disk.

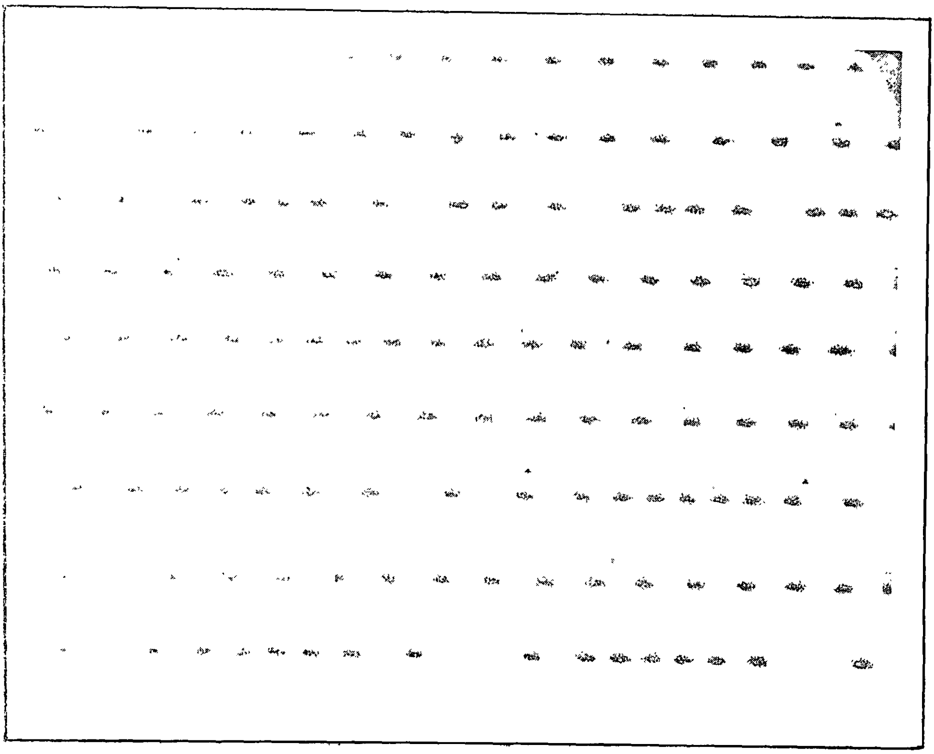


Figure 3

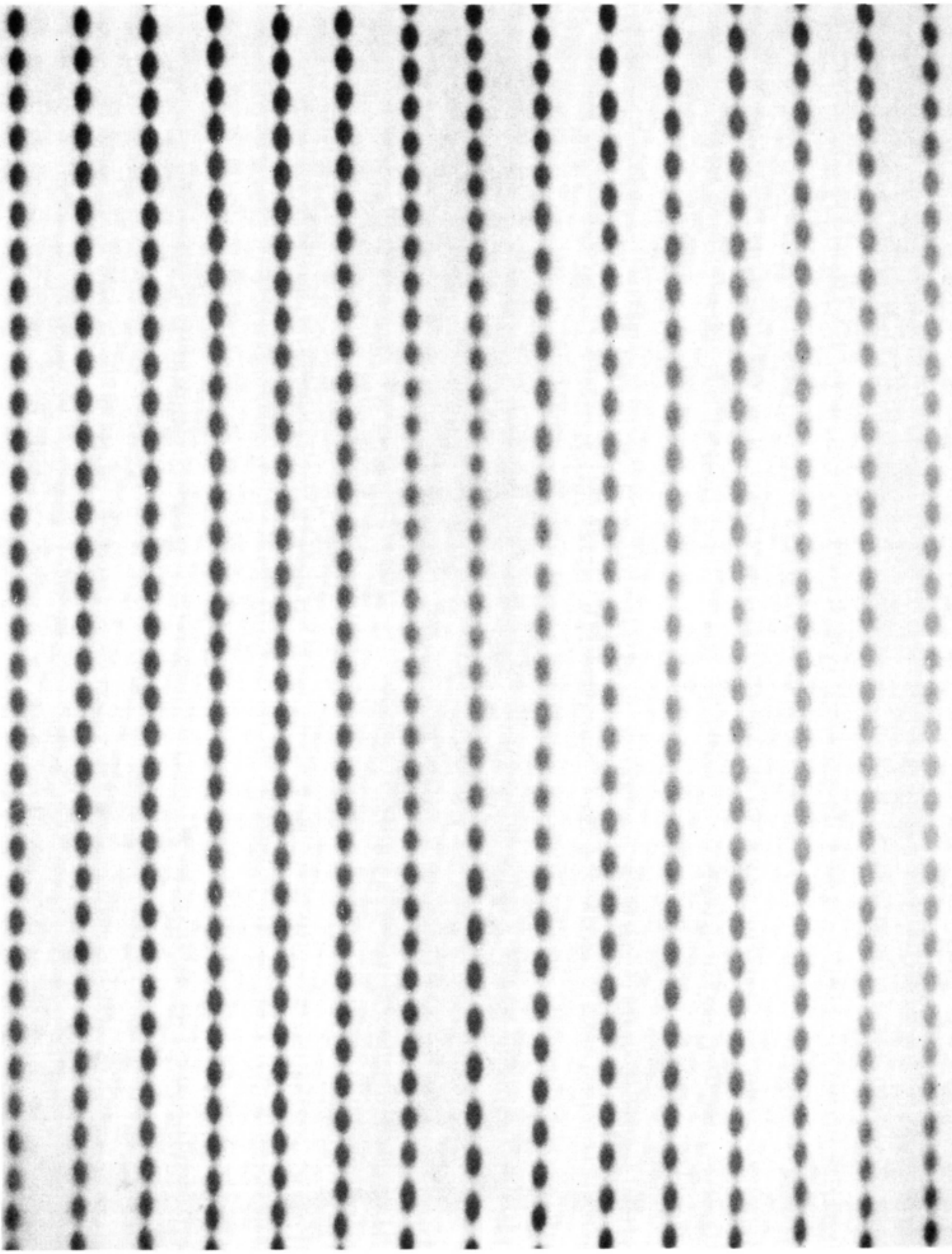


Figure 4

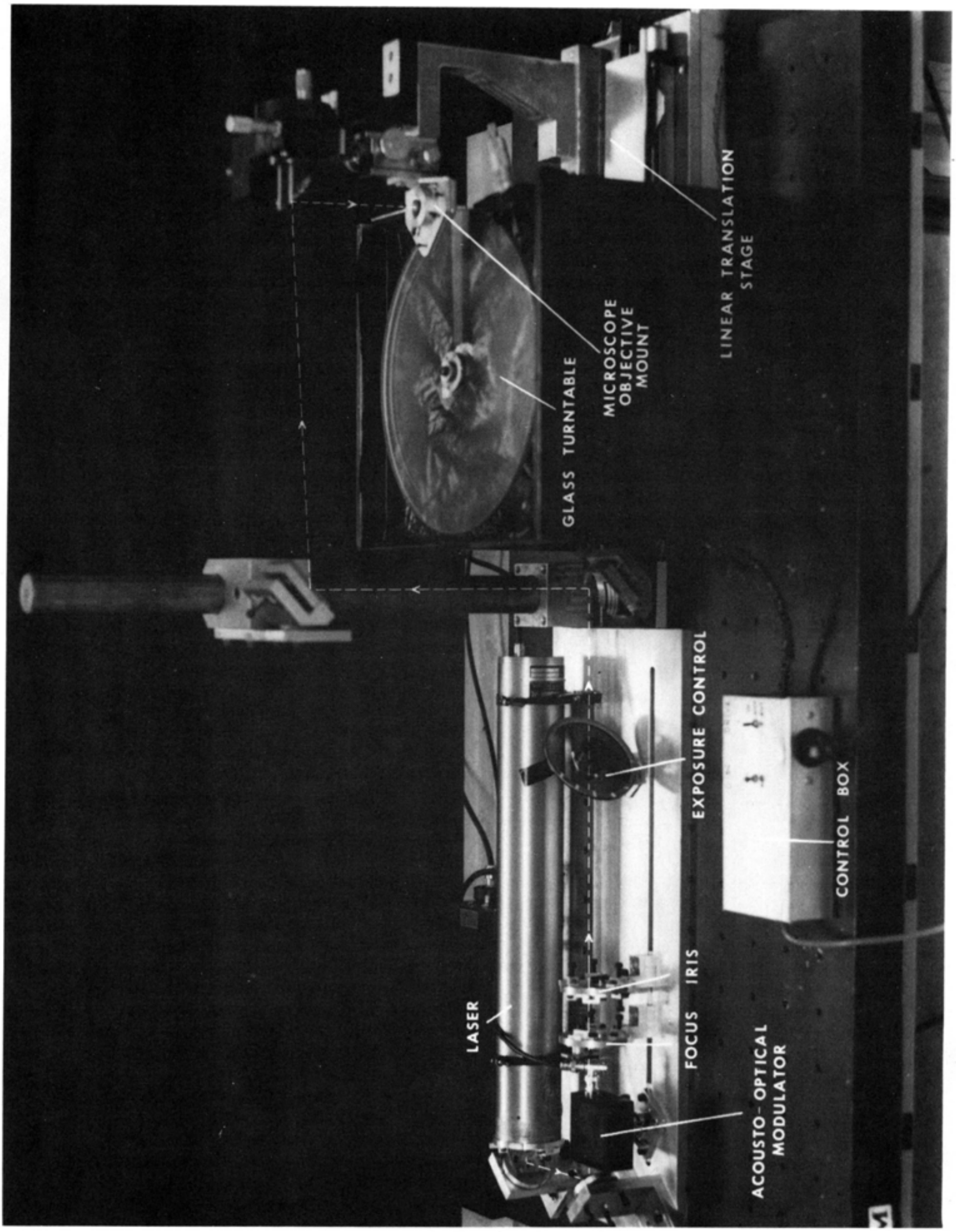

LINEAR TRANSLATION STAGE
MICROSCOPE OBJECTIVE MOUNT
GLASS TURNTABLE
EXPOSURE CONTROL
CONTROL BOX
LASER
FOCUS
IRIS
ACOUSTO-OPTICAL MODULATOR

Figure 5

The recorder is composed of relatively simple off-the-shelf components, and the limiting characteristics of the recorded signal reflect in most instances the choices made with respect to these components rather than the film itself. The frequency response of the modulated laser beam can easily be made to exceed 20 MHz. In our analog recording we typically use a modulator which is at -3dB at 7 MHz with an appropriately focused laser beam. This is more than adequate for the 4.2 MHz bandpass of the NTSC video signal. Thus, the laser spot size on the film, in combination with the minimum disk radius at which tracks are written, determines the bandpass of the recorded signal. We use a HeNe laser at 632.8 nm and microscope objectives with numerical apertures of 0.2 to 0.4. We find that we are able to obtain adequate response at a 2-in radius; the recorded signal has distinguishable frequencies to 4 MHz. With respect to recorded video signal to noise, the present limitation lies with our laser which has a beam ripple specified at 42 dB. Of course, this signal to noise ratio can be increased by any of a number of well-known techniques.

The energy required to adequately expose the typically very slow emulsions which we use is not excessive because the majority of the energy is focused into a spot on the order of a micrometer in diameter. Using a red extended response emulsion, 1 milliwatt is more than adequate. Figure 6 shows the actual appearance of the tracks in the emulsion of a video disk. This is a magnified view of a microtome cross-section of a very fine-grained emulsion 6-μm thick on a 4.5-mil Mylar base. Note that the tracks, spaced 18 μm apart, appear to have a rectangular cross-section. This rectangular profile arises because of the Gaussian distribution in energy density near the focus of the objective. With analog recording, linearity is required between the recorded and retrieved video signals. This linearity is attained by noting that at very low signal levels the track changes in opacity extremely rapidly with increasing signal level. At very high signal levels the interior portion of the track saturates and the track widens slowly with increasing signal level. Between these two regimes lies a range where the width at the track and the opacity gradient at its edge change in such a way that the recorded signal and the retrieved signal are linearly related. The exact range over which linearity is observed is dependent on the track geometry and the details of the playback configurations. In practice, the linear region is found by recording a linear staircase signal and adjusting the exposure levels for linearity on playback. Combining area and intensity modulation yields a linear system very insensitive to processing procedures. We have observed that variations in exposure by up to a factor of two have little effect on the video display of luminance. Once the latent image is recorded, the film can be developed at room temperature using standard darkroom techniques. The emulsion sets up quite rapidly and the disk can be spun dried in a few seconds. In all, the film disk can be on the playback machine within 10 min of the completion of recording.

We stress the ease of recording for it enables one to use the video film disk in those limited-run, 10- to 1,000-copy type of applications which cannot be suitable to other video disk technologies. It is instructive to compare the recording process just outlined using film with the typical process of recording for a video disk pressed from polyvinyl chloride. With this latter process, a 14-in optically flat glass master must be sputter coated with an ablatable metallic material such as rhodium. A spiral track containing the video information is generated by selectively burning away the metal coating with a high-

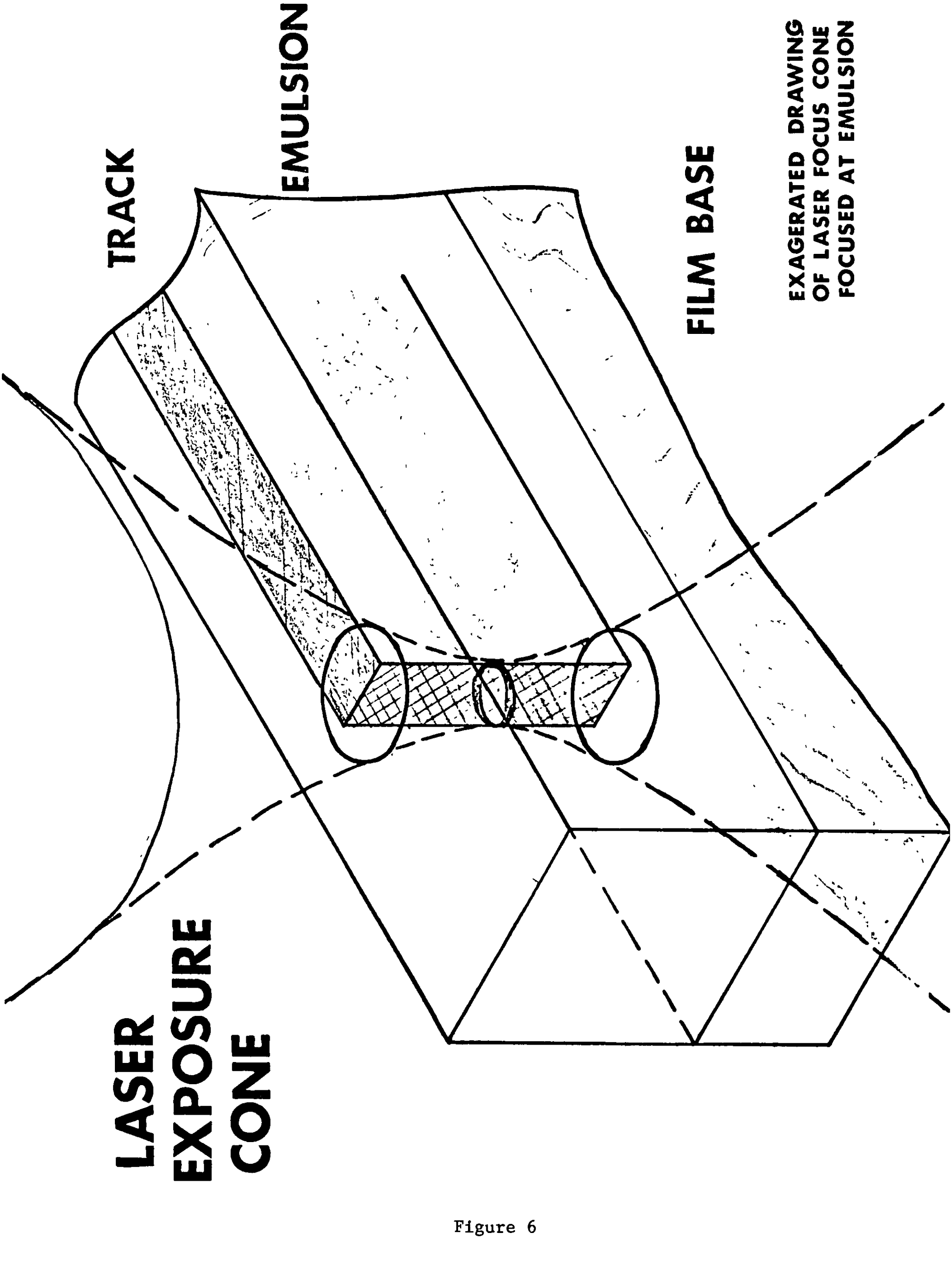

TRACK
EMULSION
FILM BASE
EXAGERATED DRAWING
OF LASER FOCUS CONE
FOCUSED AT EMULSION
LASER
EXPOSURE
CONE

Figure 6

power Argon laser. The master glass plate is demounted and coated with a photoresist material. The plate is then exposed from the rear to ultraviolet light. The unexposed photoresist material is washed away with an appropriate solvent, and this leaves a bumpy surface on the master with the video information encoded in the surface structure. This master is then treated by electrodeposition to form a metal tool from which the playable copies may be stamped from PVC disk. There is a final step required for some of the PVC video disk systems--the pressed disk copy must be metallized with a shallow metal coating. Obviously this complicated recording technique cannot be easily applied to those situations in which only a limited number of disks are needed.

An important characteristic of the recorded signal can be deduced immediately by examining the microscopic structure of the disk, namely the time base stability of the recorded signal. Whenever you see a portion of the disk with a horizontal retrace interval or some other characteristic feature of the video signal recorded you may deduce immediately that you have a built-in time reference. For example, we know the time interval associated with the horizontal retrace interval; looking at the wiggles in the radial direction of the disk we can see that there is a several-microsecond variation over a millimeter or so of the disk. This sets a lower limit on the time base stability of the signal and playback when a perfect playback instrument is used.

Playback of the video information stored in the spiral track of the film disk can be accomplished in a number of ways. One approach used in numerous other disk systems would be to focus a laser-generated light beam to a micrometer spot on the disk and detect the resulting intensity modulation as the beam is swept along the track. Another approach would utilize some form of coherent optical processing of a laser beam scattered through the film.

The simplest approach (fig. 7) is the most attractive. A small area of the film is flooded with white light. A microscope objective images the film surface with its track information back onto a micro-area light detector. As the disk is rotated the light source and objective traverse a radial path, reproducing the motion of the original write-hand. Essentiall the video playback device is a simple microscope. This approach has two major advantages: (1) An inexpensive white light-bulb may be used for illumination, and (2) the image of the area of interest on the disk surface is presented at increased magnification for subsequent processing. It is an easier task to extract the desired information from the appropriate video track in this magnified image than at the disk surface itself.

For the video detector, one can use a masked photomultiplier tube, a channeltron, or a silicon photodiode operated in the avalanche mode. The most important criterion is that a suitably small active detector area be used. Successful video operation has been attained by limiting detector areas to a maximum of 0.1 $mm^2$ with typical magnifications of 20X to 100X at numerical apertures of 0.4 to 0.7.

There are many tracks imaged into the vicinity of the video detector, on the order of 10 to 100 cm. The appropriate track is maintained on the detector against excursions due to mechanical tolerances by using an oscillating mirror in the optical path between the microscope objective and the detector. The servomechanism may be either a wideband,

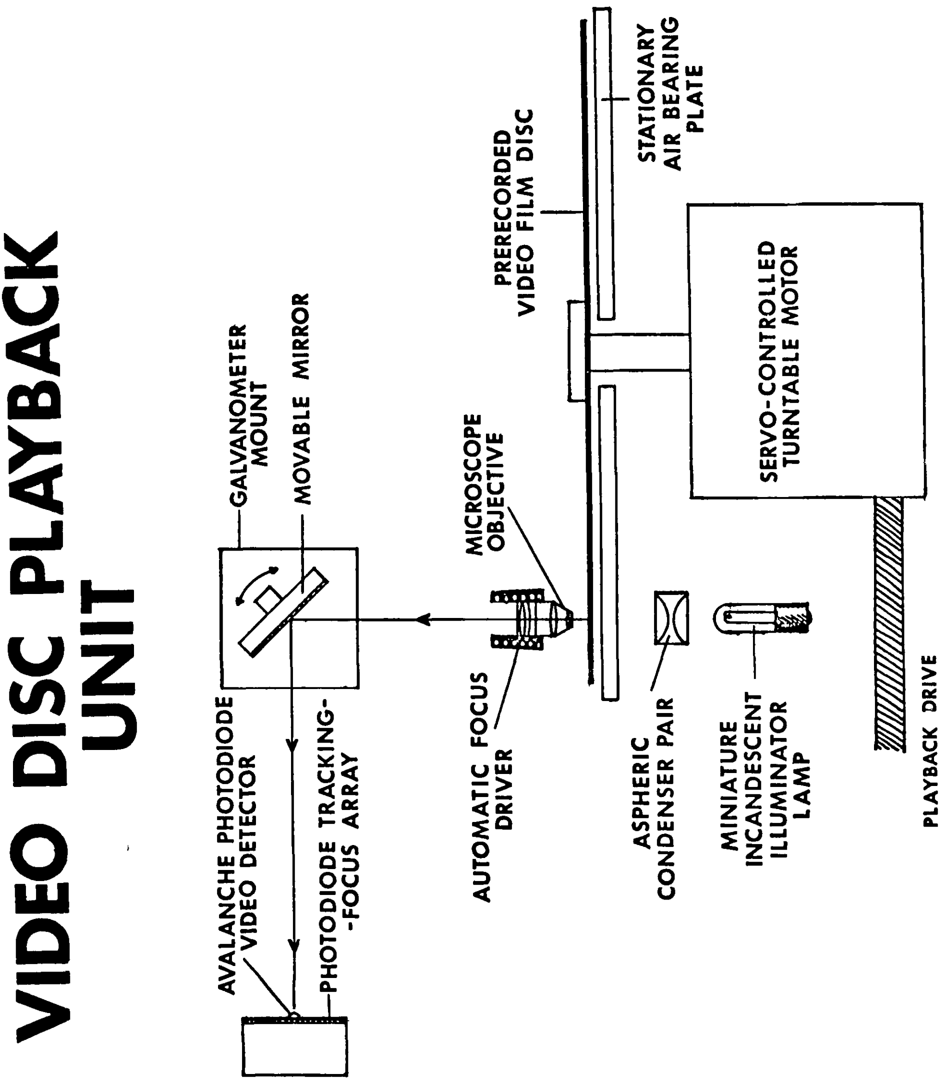

VIDEO DISC PLAYBACK UNIT
AVALANCHE PHOTODIODE VIDEO DETECTOR
PHOTODIODE TRACKING--FOCUS ARRAY
GALVANOMETER MOUNT
MOVABLE MIRROR
AUTOMATIC FOCUS DRIVER
MICROSCOPE OBJECTIVE
PRERECORDED VIDEO FILM DISC
ASPHERIC CONDENSER PAIR
STATIONARY AIR BEARING PLATE
MINIATURE INCANDESCENT ILLUMINATOR LAMP
SERVO-CONTROLLED TURNTABLE MOTOR
PLAYBACK DRIVE

Figure 7

closed-loop configuration or an open loop, tuned to the basic rotation rate of the disk. The position of the desired track is sensed by a linear detector array (in the simplest case a split photodiode), and an error signal is generated to drive the mirror to the appropriate angular position.

The use of an incandescent lamp as the source for reading the video disk is only a convenience, as any appropriate light can be used. Naturally we have experimented with a laser readout of the film disk, and we have seen very interesting results. The laser allows us to push the film to its limits of resolution, something which we are not doing in the present configuration. In conclusion on this point, the film appears directly compatible with the laser-based optical disk systems.

Given a perfect video disk recording, the signal to noise ratio in playback is determined by the intensity of the light source used. For an incandescent source a calculation of the expected signal to noise ratio must include consideration of the temperature of the filament, the transfer efficiency of the condensing optics, the maximum density of the film, the transmission efficiency of the viewing optics and its associated mirrors, and the sensitivity of the detector averaged over the emission wavelengths of the filament. Making the appropriate assumptions about these parameters suggest a 40-dB signal-to-noise ratio is attainable at frequencies below 4 MHz. Much higher values of signal to noise can be obtained simply by turning up the intensity of the light source, but with considerable penalty in terms of the lifetime of the bulb.

Duplication of the film master is by contact printing onto a silver halide film or a diazo copy. The latter material appears to offer distinct cost advantages with large runs. For best results in the usual playback configuration, a diazonium salt absorptive in the near infrared is needed. We have tested an experimental diazo of this type, currently available only with hand-applied emulsions. This emulsion offers nearly the same density range in the near infrared as the silver halide film and is appropriate for use in a video film disk application. Figure 8 shows the appearance of an original disk and its diazo copy.

The contact printing is done with a bellows press to insure intimate contact between master and copy. The equipment for copying may be scaled for application to extensive copy runs, although to date in our laboratory we have, of course, not carried out experiments at production levels.

A summary of some of the implications of the emerging video disk technology is given in table 3--hardware and materials costs associated with the storage of 10 k to 100 k frames of visual information, in a format suitable to video display--30 frames/sec at a bandpass of 2.5 MHz, approximately the capability of the system currently in use. (If the storage requirement is for audio rather than visual data, capacity can be increased by a factor of 100.) The table reflects our own laboratory exercises in producing a video film disk. Of special interest is the utility of the film video disk in the applications for only a limited number of copies. The cost of materials for making the master film disk is negligible, and the

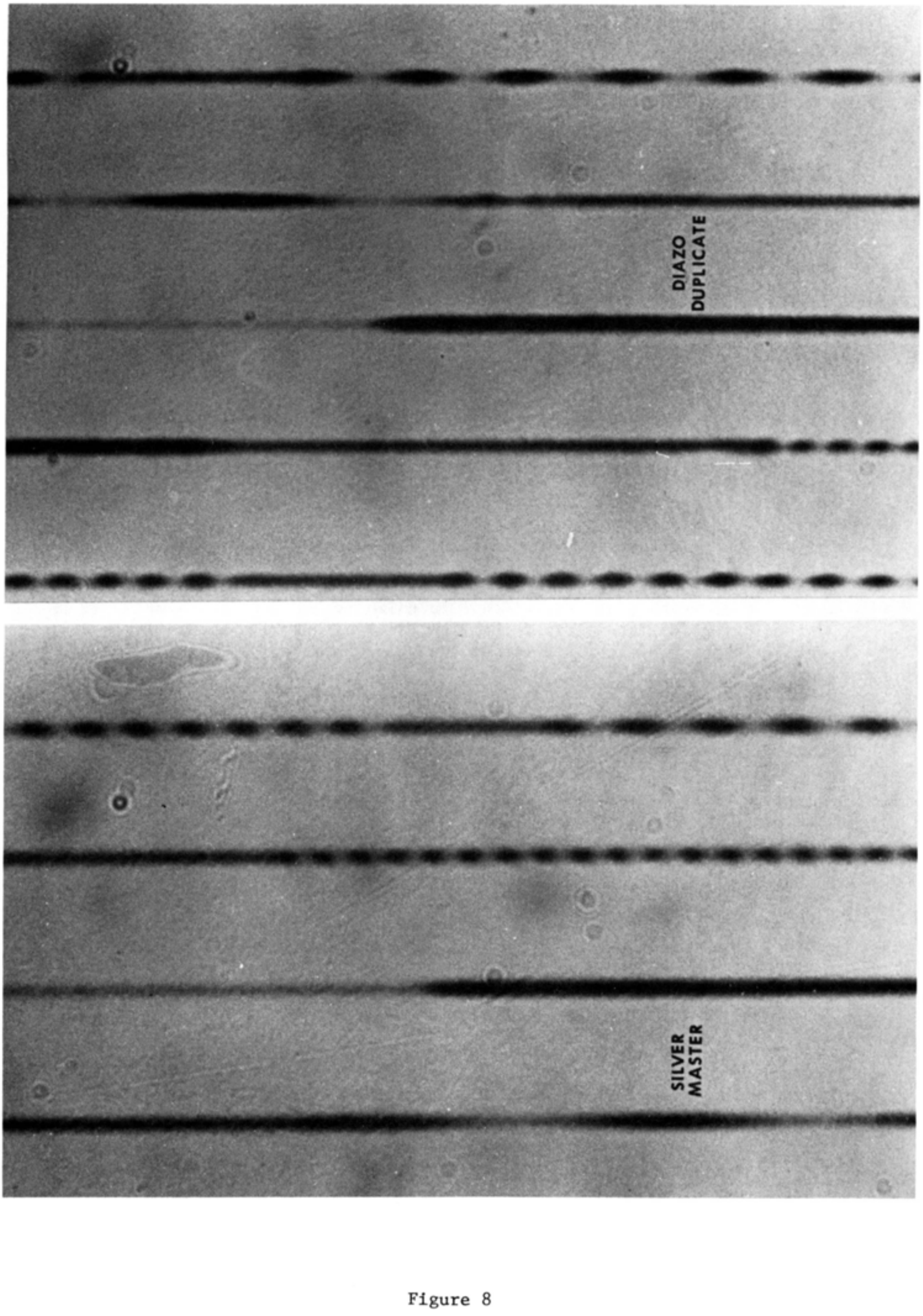



Figure 8

Table 3.--Hardware and costs for storing 10 video frames.

| Process | Instrument | Medium | Time Requirement | Cost Equipment /Materials |
|---|---|---|---|---|
| 1. Recording of visual data | Laser recorder w/NTSC input | Silver-halide, 12-m-diam. film disk | Real time | $15,000 /$2.00 |
| 2. Development master | Darkroom and apparatus | " | 10 min | $500 /pennies |
| 3. Duplication, 1-1000 copies | Low-speed duplicator | " | 1 min/copy | $5,000 /$0.40/copy |
| 4. Duplication, >1000 copies | High-speed duplicator | Diazo 12-m-diam. film disk | 2 sec/copy* | $20,000* /$0.19/copy |
| 5. Playback of visual data | Video disk player | Video monitor | Real time | $300 /NA |

*Estimated, Oct. 1974

recorder itself is inexpensive. The technique is easily practiced. The resulting disk can be used in the usual video applications, to amuse, entertain, educate, and inform. Or, in a more typical audio/visual application, one video disk can contain tens of thousands of distinct pictures relating to catalog stores, voucher files, financial accounts, text materials, personal memorabilia, historical documentation, inventory lists, data repositories, and related informational resources.

Peucker: For those who are not familiar with the whole thing, we should be aware that this was not a hardware session but a "bigware" session. There is a lot of machinery around which we--the little guys--can use. The emphasis is heavy on large systems; except for the last two papers which were development reports. The first three talks represented the kind of IBM mentality that we find so often in the American government--think big, charge the taxpayer, but leave your brain at home. I think that is the basic idea.

Schwartz (Jet Propulsion Laboratory): Some of the speakers have talked about the precision of the EBR--3-μm and 12-μm--but as for accuracy, not much has been said. I wonder what is the geometrical accuracy of these devices? My experience is that it tends not to be anywhere near as good.

Carr: We have various kinds of accuracies.

Grosso: The 3 μm that we talked about was the recording spot size. The accuracy that they are getting with the ERTS EBR from film to film, day to day, is about on the order of 1 part in 5,000. Geometrical accuracy can be achieved towards 0.01 percent, but this takes a lot of carefully controlled conditions.

Constantine: I would say that the accuracy depends on how much time and money that you want to invest in all the components back of the final display. As Pat mentioned, 0.01 percent is not unreasonable today in terms of the precision deflection yokes, amplifiers, and linearity correction systems available. Then you get into the problem of how large a word you are going to use in the computer. Everything gets bigger and more costly as you try to improve accuracy.

Healey: The type of work that we do is concerned with gray level in systems that record data as from ERTS, which have already been digitized. My experience has been that CRT devices have about a 5-pixel error over 1,000 to 2,000 pixels, where the beam is degraded on the edge of the CRT more than the center.

Carr: With ERTS imagery, the basic image is not digitized and corrected--this is done during the recording. The EBR is programed beforehand, and these corrections are introduced--that accounts for its very high throughput. If you had to go back and digitally correct each image from the ERTS sensors, it would cut down the throughput tremendously, and it would be very costly.

Snow: On the 14- by 14-in large-format scanner, we guarantee accuracy of 0.05 percent or about 1 spot size.

Edson: I am going to respond to Peucker's comment about equipment cost. I think that, by and large, we should be looking to industry to provide capabilities in the future. I think it is true that systems are very expensive and have tremendous capability, and the small user cannot possibly afford this sort of thing. Industry should be able to provide service facilities for the small user.

Chrisman: If I may answer for Puecker: I think that when you get these "megadevices" and such absolutely phenomenal laser memory storing data bases, we will never be able to get them on the sort of machines that are used for day-to-day analytical work in municipalities or in academic environments. Those devices are for a very long time and very few installations. I think that we should be talking about hardware in terms of something that is reproducible at more than 2 or 3 sites in the whole world. That is what Puecker and I are really saying.

Carr: That is an interesting idea. Maybe with the world of minicomputers coming on us, we will see more and more of that in the next 10-yr period. i/o Metrics has a very interesting device for storing digital data; I think that we will see optical storage replacing magnetic storage in a few years. Hopefully, the problems of bigness will become ones of smallness.

Boyle: I've heard a number of people say that they wished there was more time for discussion, the panels this afternoon will give somewhat shorter presentations. If they don't cover everything, forgive them and ask the questions. I felt that we were just getting to the stage where we might have a nice little battle, and I was sorry to see us break for lunch at that point. The only thing that we will limit is Tom Peucker to about 4 appearances; don't take his words seriously about being the little man--he is only jealous.

The next panel we have is probably the present love of my life--interactive editing, the interactive graphic manipulation of cartographic data. We have a very good panel to lead into questions; they are involved in the work at the moment and have good ideas.

Connecting with this morning's discussion about the raster-scan plotters and so on: From the hardware point of view there were 2 sorts of displays which are used for interaction. One is the normal refreshed display, that is, the standard sort of television display where you have raster lines, which is used very frequently. This is very much better for alphanumeric line-by-line displays than for true cartographic displays. Certainly, the storage displays seem to be much better and preferable for most cartographic uses. You can store much more detailed data; you don't have to get everything there in 1/60 sec; and you have quite a lot of advantages.

A problem also discussed was converting from an ordinary data bank of line vectors to the scan mode for drum plotters. I haven't been involved with drum plotters, but we have done a lot of experiments using standard television displays on computers. It is somewhat of a similar problem, I am sure. We convert from our line data in the PDP-8, a small computer, to the scan line form, and we have to produce a scan line every 60 μs; yet, this can be done. It is a smaller amount of data which you are converting, but you have to do it faster than for a raster plotter. There is not a great deal of difficulty. Our aim is to be able to use standard color displays which serve lots of uses. Unfortunately, we don't have any storage displays which work in color.

Just to mention two people who were not able to come--Laser Scan from Cambridge, England, and Tektronix. We are not leaving out the ordinary, such as the plotters. We didn't ask CalComp, Gerber, and Xynetics, not because their equipment isn't very useful in this area, but we felt that most people knew about them and would like to learn something about the newer devices that are coming.

Now I am going to hand the session over to the moderator of the editing methods panel, a person with a great deal of experience working with David Beckmore at the Royal College of Arts in London, in the experimental cartography unit. He has now left there and is a professor of geography at the University of Durham in England. He will certainly point out all the possibilities and variations.

## Editing Methods Panel

David W. Rhind, Presiding
University of Durham, U.K.

Frank P. Edmondson
Central Intelligence Agency

George Steinke
CALMA Corp.

Walter M. Anderson
Applicon, Inc.

Barry K. Moritz
PRC Information Sciences Co.

Rhind: Let me introduce the panel members. The first to talk will be Frank Edmondson, a staff cartographer at CIA, with 3 yr of experience working on World Data Bank II tapes. This is an essential way to start; indeed I am going to emphasize the importance of the user end of editing methods. Following Frank, we will have George Steinke of the Calma group, and following him will be Walter Anderson; both of these speakers work for commercial firms and have had long and valuable experience in computer graphics. The afternoon will be closed with a short talk by Barry Moritz. Barry has an extensive background in mini- and maxicomputers and with a wide variety of data handling ranging from communications software to graphics. He will be talking about the PRC project for linear input system, but I asked him to stress the editing of raster data. Initially, he will cover user aspects, then a couple of applications of line editing, and finally, I hope, some consideration of editing raster data.

Anyone who has been involved in digitizing map data should, within a very short time, have their "hands covered with blood." It is almost impossible, in my experience, to digitize data without accepting, given our present technology, that there are going to be a lot of errors in that data. Data is not clean; the user must decide just how dirty he is prepared to have it. I would argue that, in fact, cleanliness of the data must be related to the task, and here, if I may take a stab at fellow cartographers, the standards of data cleanliness are often not dictated by the real requirements and the accuracy of the data, but by the historical connotations. In other words, we have always had nice clean data in graphical form. We want it the same way, even if it doesn't matter, even if this cleanliness is not justified in terms of data accuracy. I believe that we want to have our data only as clean as necessary because it costs more if you have it cleaner than that.

It is amazing how some people still do not see the need for an editing capability: One case in the U.K. recently came to light where someone who went to work for a large local authority opened the door and nearly 1,000 paper tapes fell on him. These had been digitized over the preceding 3 yr but were completely useless and subsequently burned because the people had no decent editing capability.

Another point is that I think that a real distinction has got to be made between finding errors and fixing them. You may very well not use the same techniques for both functions. In "finding" and in "fixing," you have to look at the two aspects of the data--its geometry (and/or the topology) and its attributes. How do we check data for errors? We can apply visual, logical, consistency, or sample checks. The first has always, to my knowledge, been carried out by simple "eyeball" comparison of plotted output and the original digitized document, although the possibility of comparing these in stroboscopic light might usefully be investigated. The greatest danger about visual checking is that you are dependent on the checker, and once he has checked a document, he will be convinced that it contains no errors. Certain logical tests, such as "is this point within the map bounds?," can easily be carried out by machine as can some types of consistency checks on redundant data, such as "is the sum of the depths to various geological strata equal to the supplied value for its total depth?" In current cartographic work, the onus of digitizing (and processing) the input data twice has meant that consistency checking to date has been done merely on attribute (code) data or on selected (e.g., line start and end) points from the geometry files.

Another interesting point is the frequency of editing: Do or can we do it all at one stage or must it be an interative process? A final point which might promote discussion is the cost aspect. Interactive digitizing using cathode ray tubes is seductive, very pretty, good fun, and exciting. But is it anywhere near as economic as offline working? There are a couple of commercial companies in U.K. at the present time who make no use of interactive digitizing because they find that a standard, very simple offline digitizing process, correcting the errors afterwards on a test plot, is still much cheaper than running a minicomputer linked to a standard digitizing table. In discussing costs, I suppose we are all aware how critical the technological aspect is: in addition to changing digitizing costs, the technology that we were hearing about this morning from i/o Metrics and others may present us with rather different editing problems from those we have had in the past.

Edmondson: I am one of those Government users that Dr. Boyle mentioned this morning. In the few minutes that I have, I will describe some of the editing techniques that have been used at CIA to produce a small-scale world data bank at an average input scale of 1:3,000,000. Coastlines, rivers, boundaries, and selected transportation have been input to the data bank for over 80 percent of the land area of the world. The bank now totals more than 5-million latitude/longitude points. Our objective is to create a world data bank that may be used to make small-scale maps of any area of the world, using 16 different projections at various scales and sizes. To achieve this flexibility, data are stored as one world data bank in latitude/longitude coordinates. Figures 1 and 2 are samples of maps made from the data bank. The line work is plotted, and the type and tones are added manually by cartographic technicians.

Since we do not have an interactive digitizer, all of the raw data are recorded, including any mistakes that may occur. Experience showed that most of the time the operator is aware of his digitizing

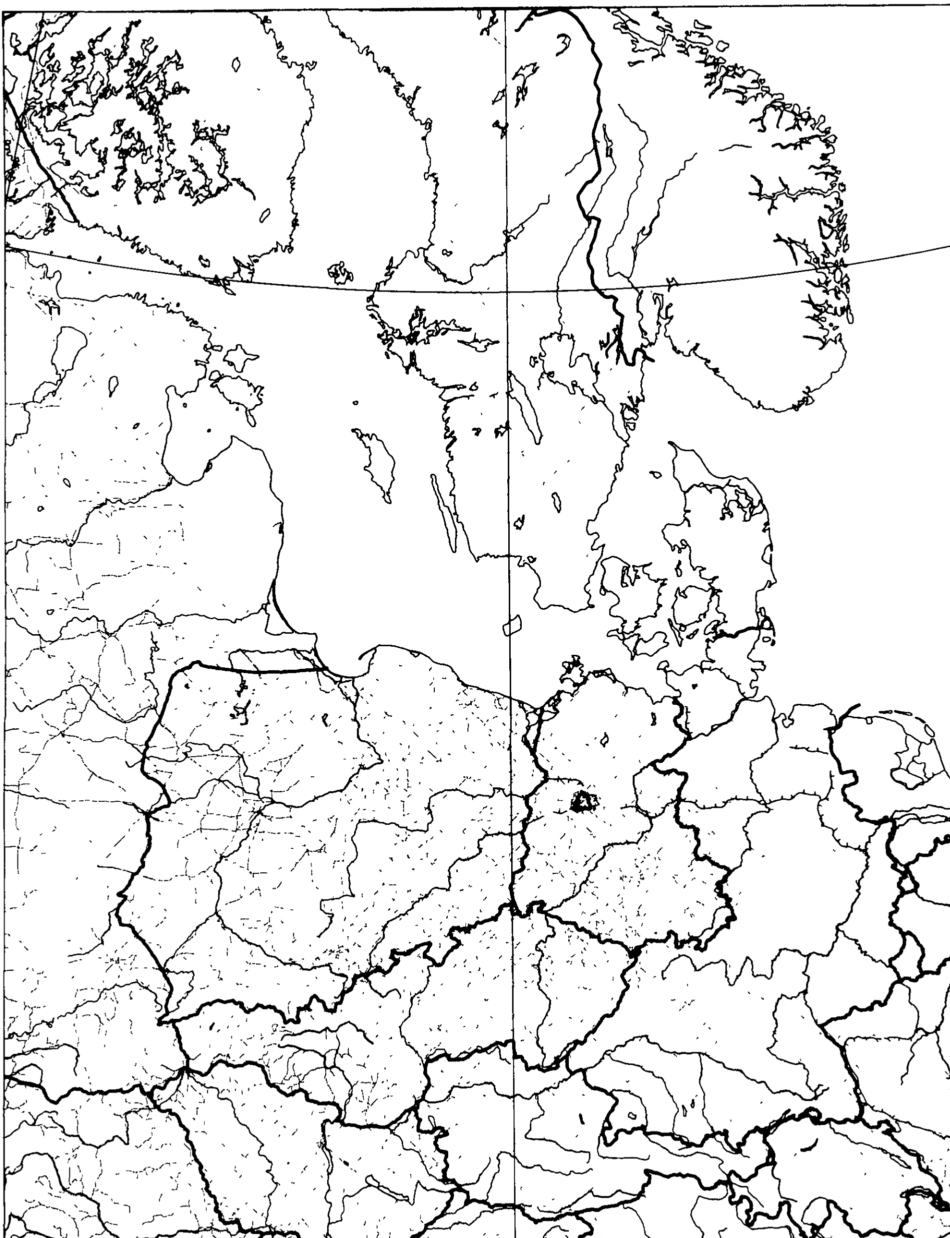


Figure 1

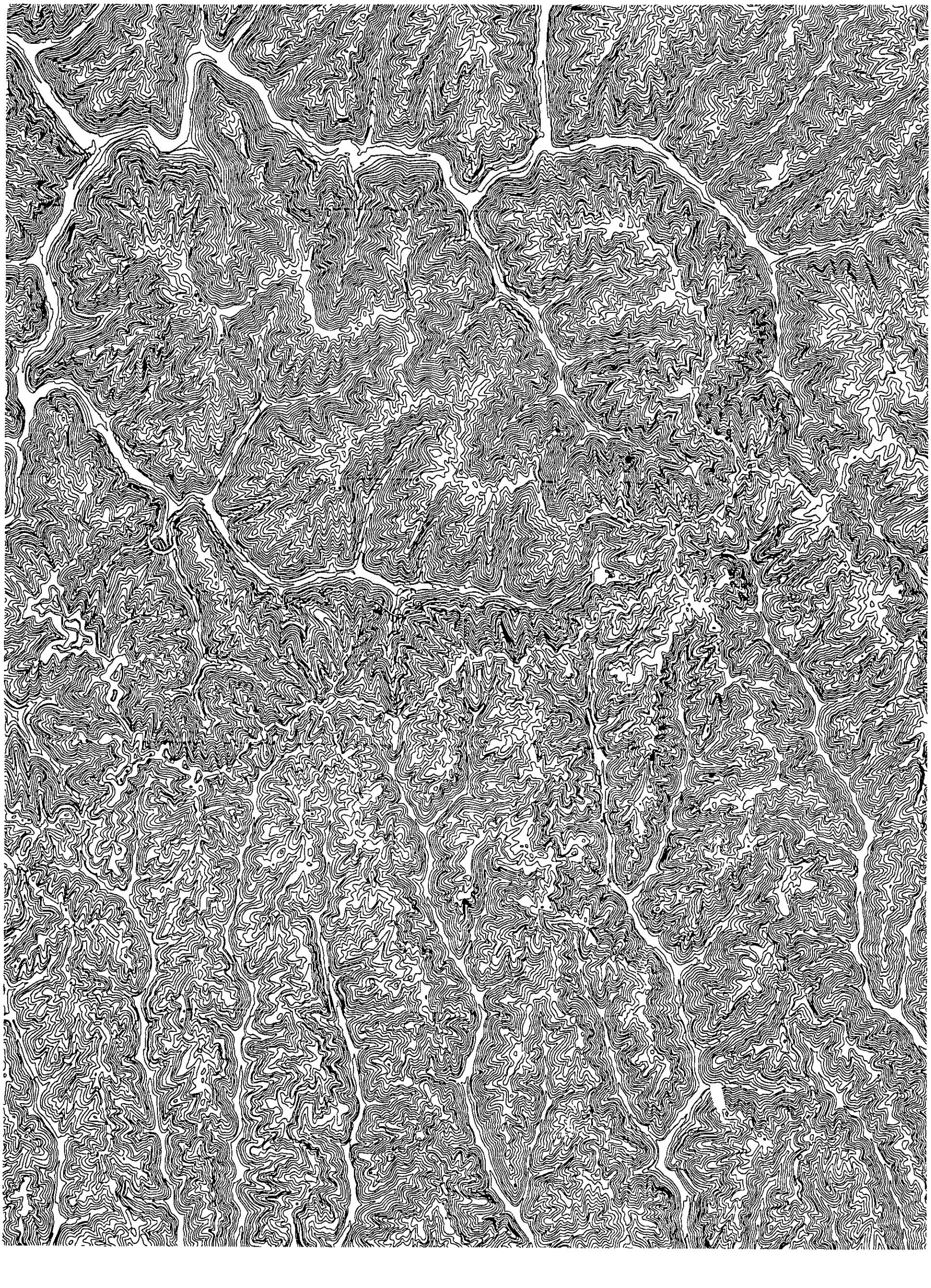


Figure 2

mistakes. For instance, when he follows the wrong line, gets too far off the line he is trying to follow, or does not join a river to a coastline correctly, he realizes his error, but the incorrect data have already been recorded. Thus options were added to our rotate-and-scale (R&S) program, which processes the raw digitizer data so that the operator can do some editing while digitizing. He may flag the incorrect line with the appropriate code so that it will be deleted completely, or he may flag for a partial deletion and redo only the portion of the line that is incorrect. The partial deletion and the automatic closing of the line save a lot of interactive editing time. The automatic closing of lakes and islands by this program also speeds up the digitizing since the operator does not have to try for a perfect closure. The R&S program also eliminates duplicate points and creates new points between 2 original points so that lines can be digitized point to point rather than in the stream mode.

After processing by the R&S program, the data are plotted on film and compared to the original map compilation. Corrections are then made interactively on the IBM 2250 which is online to a 360/65. For the most part, the digitized data are accurate enough but do require some cleaning, as was mentioned this morning, for the correct appearance. Gardner Hill of the Ordinance Survey refers to this as "cosmetic cartography". A point or two may need to be added or deleted from the end of a line to make a smooth intersection. Boundaries that follow rivers will not look correct unless the points in the rivers and the boundary are identical. We digitize them once and store them on separate files. All of these corrections are done interactively on the screen, so that you can see they are done correctly.

Since data are added to the bank one sheet at a time, it is absolutely essential that new lines join correctly with those already in the data bank. This is accomplished on the IBM 2250 by displaying the adjoining lines already in the bank and adding the new data to join them correctly. All of this is done in x-y coordinates on the IBM 2250. The final step is to convert this to geographic coordinates and file it on the disk.

In summary, I would say that with a skilled operator and the R&S program cleaning the data to some extent, the number of corrections that have to be made interactively on the IBM 2250 is usually quite small.

<u>Wilkie (Dynamap Ltd.)</u>: What percentage of the actual digitizing time would be used in cleaning the data?

<u>Edmondson</u>: Approximately the same time is used--slightly less editing time than digitizing time.

<u>Niedermair (National Ocean Survey)</u>: I find that these corrections tend to eliminate the useless points. How do you do that?

<u>Edmondson</u>: The R&S program throws out all duplicate points. This is the raw digitized data that are run through the program which will eliminate duplicate points, if there are any, within the same geographic line or feature. We just couldn't get off the ground with manual methods; I hope to never go back to graph paper and plotting points.

Falke (National Ocean Survey): I would like to know what the resolution of the information you are storing is, in terms of 0.001 degree or 0.0001 degree.

Edmondson: We digitize at approximately 1:3,000,000 scale, maybe a little larger or smaller, and sample a point about every 0.5 mi, if you are talking about distance on the ground.

Bonham (Chevron Oil Field Research): Do you have the graphic design feature on your IBM 2250 for the input of the edited data that allows you to screen data in on the tube; or is it point by point?

Edmondson: It is point by point, and the screen is limited to 1,000 points at any one time.

Steinke: Calma has recently introduced a new product in its line of cartographic equipment--the Calmagraphic Interactive System. The new system is based on a data base of 48-bit words and was designed to allow 3 or 4 main functions: (1) record input of cartographic data, (2) easy editing of this data online interactively, (3) a certain amount of computation, such as volume, area, and smoothing; and (4) the option to produce a tape of this data for processing on a large computer system. We will interface virtually any computer system in the world today.

The hardware is based around a Nova minicomputer. This is a completely offline system with a disk drive and a tape drive for the central section. We have input "stations" which consist of an interactive digitizer, a CRT, and a keyboard. An edit station provides 11- by 11-in interactive area that you can digitize and edit from, as well as a CRT and another keyboard for entering commands.

Before I get into the editing, I would like to give you a quick rundown of our data structure so you will be familiar with the terms. The first way that we identify anything is a drawing name that can be up to 15 characters long. Immediately after this, as a next classification of data in our tree-structured data base, we have a set of overlays which are numbered from 1 to 32. Below that in the tree structure, we have domains. We may have up to 32 levels of domains; at any one level, we have virtually unlimited domains available to us. For example, if you had a map, you could be talking about Overlay 1, and your drawing name could be Map 247; then at your first domain level you could have things like topography, improvements, and property lines. Under improvements in your first domain structure, you could have public, private, and commercial improvements. These can be broken down into a third domain level, such as streets, highways, buildings, and bridges under public. This can carry on for 32 levels. Attached to any group are overlays; attached to any overlay or domain you can have a group. A group is just a collection of related data items. You can have 1 to 65,000 groups, and a group of 1 to 65,000 could be attached to either a domain or an overlay.

Another item in the data base is an information block. The information block contains either numeric data, alphanumeric data, or computations such as area or volume. There can be one or more information blocks associated with any group, domain, or overlay. As another way of representing information, we also have associated a line-type table with an overlay. A line-type table contains from 1 to 32 different descriptors that tell you how pieces of information will be displayed. If you have a set of points that represent a line, they can be represented on your output device as a line that is 5 mil or 10 mil wide. You can also associate a different line-type table with each overlay in the system.

If you have an interactive system, first you need to be able to view the data that you have entered into the system. Several commands exist for this. We are able to define a window on our CRT, magnify the window, shift the window, and contract the window. We are also able to specify what data will be viewed. We can say we want Overlay 1 and Overlay 3; then we can also say we want to look at Overlay 1 and only a particular number of domains. We can also go down into the group level and specify which groups we would like to see.

I like to think of our edit commands as three types. In one type we can edit the data in the information block, and we can add, delete, rename, or add to the data blocks. We can also alter the information in the data blocks. At any time after you have entered the information--concurrent with the digitizing operation--you can stop and call the information from a previous drawing back into working storage. You can evoke the editing commands then, which at this point are usually limited to a particular overlay.

If you are going to modify some data, first thing is to identify it. One way of doing this is to define a window--again, we have a wide range of commands to pick out a particular window. After the window is picked out, we can specify that the item to be edited is inside, outside, or partially in the window. We also have the capability to search for a particular group by positions. Once we have identified a group, we are able to operate on that group in several ways. We can delete the group, copy the group to a new location, translate the group, or rotate the group.

As a further feature, we are able to operate on the individual items in the group. We can add items to a group; if you have missed a point, you can add a data point in. You can delete spurious data points, move points, and reshape lines. If you have a segment of a line that is badly digitized, you can erase and redigitize that segment. You are also able to do text editing on the items in the group. You can insert or delete symbols, which are items of the group. As a final feature, on the particular items in the group, you can change the line types for a different representation. Two other editing commands that I want to mention really quickly are: (1) you can always go back and rename your drawing, and (2) if you have several drawings that you want to merge into a large drawing, we have a merge feature for this particular data base.

We have an interactive data base that we are able to view in various ways, and we have a large number of commands that allow us to edit either the information block, the entire group, or the individual elements of the group.

Wilkie: When you erase data, do you in fact delete that data from your file, or do you tag it and retain the old data?

Steinke: The data are tagged as deleted, that is, the data have an identifier on them that says they are deleted. If at some point you want to go back and get that data, there is an unerased command in the system that allows you to go back and re-retrieve it if need be.

Anderson: Applicon has been in the interactive brackets business, producing minicomputer graphic systems for about 5 yr; it was just about 2 yr ago that we began to get inquiries about applying our system to mapping. Previously, most of our work was done with integrated circuit mass and printed circuit boards where it was clearly very cost effective and where we had quite a bit of background and expertise.

In talking to people about mapping applications, it became very clear to us that while we didn't have most of the software required, we did have many of the interactive techniques and graphic concepts that were clearly applicable. Layering in a printed circuit board is not much different than layering in a map. The mechanical line types are not too much different than the symbology necessary for railroads and rivers, etc. The concepts of windowing on a CRT over a map are ones that are probably more satisfying than windowing over a IC mask or a printed circuit board where it seems much less natural. Most importantly, we have developed some tools for multiprogram operation of a minicomputer and large disk systems.

(Slide) (Editor's note: Slides not available for publication.) The first slide shows a multiactivity system that was displayed at the ASP/ACSM Fall Convention in 1973. On the right is a free-cursor digitizer, a Bendix digitizer in this case. In the center is our Applicon editing console, and on the far left is a Xynetics plotter.

(Slide) This slide shows the central operating terminal with the stylus in the front. The operator works with the stylus, viewing the CRT. All of his motions on the tablet are mirrored in the CRT, which is quite simple to use. It does not take very long to pick up the editing techniques of selecting, moving, adding, windowing in, and blowing up small areas to very large drawings.

(Slide) The next few slides will show some of the possible graphics terminals that you might have. This one is called our tabletizer. It is a large-surface tablet which can be used with the two styluses that are shown at the top--one is nonmarking and one is marking. The display on the right is simply an alphanumeric display (no graphics there).

(Slide) This slide shows a similar large-surface tabletizer which is somewhat larger and backlit. On the right is a 19-in CRT, and on the left is a digitizer cursor which can also be used in lieu of the stylus.

(Slide) This slide shows an x-y cursor readout light in which the operator can read out the ground units for the internal Applicon control units or can read out the raw units as the digitizer is measuring them.

There are several possibilities for what one might want for a cursor in digitizing. The tabletizer stylus was shown earlier; in the next couple of slides we will show a couple of other possibilities. (Slide) This is a locked-arm type of thing where it is locked into a vertical or horizontal position. It is probably not too convenient for entering or editing map data. (Slide) This slide shows a free cursor style which is probably more convenient for editing.

(Slide) This slide shows another type of input terminal which is to input and edit from a coincident plotter on top of the digitizer. One can digitize a contour, for example, and immediately plot it back to see how faithfully that line has been captured as well as to mark off what has been digitized.

(Slide) The ETH system is probably the first one that we have sold that is being used exclusively for interactive mapping. Others of our systems and service bureaus have been used partially for mapping as well as for diagraming and similar applications. The ETH system consists of a deck PDP-1140 with 28 k rapport, a tablet editing console not shown here, the Graticon digitizer, the 19-in CRT, a Calcomp 936 for check plotting, and various periferals such as magnetic tape, card printer, line reader, and high-speed teletype supporting the graphics activities. Offline to the system is a Ferrante master plotter to produce the final artwork.

(Slide) This slide shows a closeup of the digitizer; notice a couple of other possibilities for digitizer cursors. The one being held is the simple crosshair type with a magnifier attached to it. To the right is a scribing cursor that can be used on scribecoat to mark exactly what is being captured. Towards the bottom of the picture is a function keyboard for quick re-entering commands to the system. These are user definable.

A number of special editing features in the software were developed to make the ETH system productive for map input and editing. First of all, a photogrammetric coordinate transformation was added to the software to relate up to 4 points on the digitizer surface to 4 points on the ground. Ground coordinates are accepted and displayed with up to 8 digits of precision relative to a user defined map origin. Retransformation and rescaling software are provided, so that over a limited range one can change the scale of the input or distort the data for plotting back on a distorted output medium. Continuous digitizing with time and distance sampling is provided along with precise clipping of map cells which the next slide will show.

As an operator prepares to do a large map by breaking it up into many smaller maps and digitizing them one by one, he may want to digitize over the edge of the map just to make sure that he has gotten to the edge of the map cell. The map clipping software provides the ability to clip the cells precisely at the edge and also provides data that can be carried forward to aid in the production of adjacent map cells which will meet when they are later joined together.

(Slide) This slide shows those selected areas, near the edges that are removed from the map. Segmentation software is provided to merge together separately digitized map cells into a continuum of maps. Again, to aid the operator in digitizing, there is close-looped snapping of contours and also snapping to existing lines in the drawing so that lines can be made to meet without the operator having to be very precise about it.

Moderate changes in scale either up or down may result in a data base with too many or too few points. Two programs are provided: one to filter the data, to thin out a data base with too many points when trying to generalize to a higher map scale; and the second to deal with map data that are too sparsely digitized (either I did not digitize it continuously or I set the parameters wrong when I was digitizing it). The next few slides demonstrate this spline fitting.

The lights that are provided are clustering software to allow points or contours that have been digitized at different times to be merged together in such a way that when they are plotted, they will plot one after the other in the same direction. The Ferrante formatting software is part of what is provided along with software for getting data into and out of the system on cards and magnetic tape. On magnetic tape, we can go off to a larger scale computer to do processing and other data base preparation. You may want to punch cards offline to enter known ground points into the data base with components of a certain type.

The ETH system will be installed next month in Zurich. We are looking forward to working with ETH and to determining how effective the software tools will be for interactive cartographic preparation.

Chrisman (Harvard Univ.): It seems to me that you spent a little bit more time on how you were going to add more points to a cartographic file. How do you proceed in deleting points?

Anderson: Points are deleted by means of an algorithm that simply takes a starting point on a contour and places a distance-window around that point. All the points that follow on the contour (that lie within the window) are deleted. Once a point is found outside that filtering window, it then becomes the center of a new filtering window, and you pass on from one polygon to another until the end of the polygon is reached. The first and last points of the continuously digitized polygon are always retained. This was a first approach that ETH felt would probably work. The program is modular, so that as the system is used, modifications will be a simple matter.

Moritz: The subjects I'm going to discuss are from the point of view of hardware related to editing and cover experience that the Information Sciences Company has had with the Rome Air Development Center (RADC) in Rome, New York. The company has been active in cartographic work at RADC for about 5 yr. I would like to describe a few of many different projects associated with the Experimental Cartographic Facility (ECF) at RADC.

The first project I will discuss is also the most recent--the Lineal Input System (LIS). It is clearly an automated cartographic process, and we accentuate, error free. The basic functional objectives of LIS are: (1) conversion of analog cartographic source material to error-free digital data cells (files) for subsequent automated cartographic processes, and (2) maintenance of a digital cartographic data base through timely updates based upon new materials. The second objective, we feel, is just as important as the first. The existing LIS is a manual digitizing entry system which we all know is time consuming, laborious, and prone to error. However, the existing system is also very cognizant of the fact that a human being is still the best representative for deciding what an error is and how to remove it. When building LIS, it was deemed extremely important to not only produce the data but also to be able to get it in any arbitrary coordinate frame (such as the transverse Mercator and photographic frame), to get pieces of it, to correct small pieces of it, and to put back into the geographic cartographic data base that information which would prove useful for a variety purposes. Therefore, LIS maintains data; it doesn't just create it.

The goals of LIS are:

-Product-independent format

-Use of a complete, flexible classification hierarachy

-Rapid response to user requirements

-Direct support to <u>production</u> (not R&D)

-Enhancement--not elimination--of human participation

-Reduction or elimination of duplication.

A product-independent format is one in which the data base information is not specific to any scale, projection, or other parameter of specific products, but which provides information for generating a whole range of products. The classification hierarchy is based on English cartographic classification terms. Since cartography is closely allied with the presentation of important information within human understandability, these goals are considered important as they enable the interaction of man with data in a variety of ways best suited to the data being presented. The cartographic data cell or data base is based on geographic coordinates. LIS has been installed at both Defense Mapping Agency Aerospace Center and Hydrographic Center and accepted for production.

LIS is depicted in figure 1. The goal was cost effectiveness which, compared to the dollar values considered by the small user, can still be rather high when the Federal Government is involved. LIS represents an initial investment of about $400,000 to $500,000 in hardware. Although the initial system only had 5 stations, it is expandable to 10 stations. Each station is represented by one IMLAC PDS-1G and one Instronics Gradicon digitizer; the cost of these two devices plus assorted small items is under $30,000. Each station is capable of both digitization and interactive editing, as well as interactive erasure and error correction during digitization.

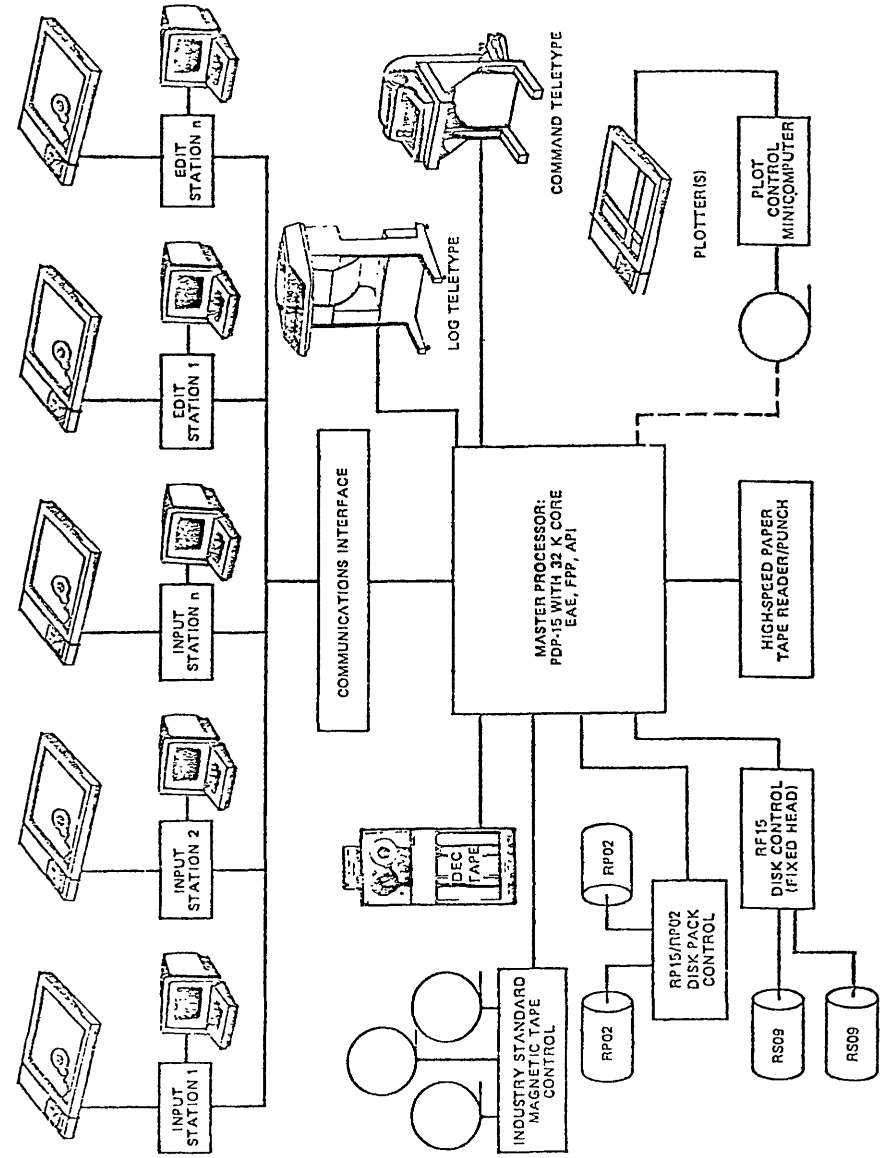

INPUT STATION 1
INPUT STATION 2
INPUT STATION n
EDIT STATION 1
EDIT STATION n
COMMUNICATIONS INTERFACE
LOG TELETYPE
COMMAND TELETYPE
PLOTTER(S)
PLOT CONTROL MINICOMPUTER
MASTER PROCESSOR: PDP-15 WITH 32 K CORE EAE, FPP, API
HIGH-SPEED PAPER TAPE READER/PUNCH
DEC TAPE
INDUSTRY STANDARD MAGNETIC TAPE CONTROL
RP02
RP02
RP15/RP02 DISK PACK CONTROL
RF15 DISK CONTROL (FIXED HEAD)
RS09
RS09

Figure 1

The major cost of modern minicomputer systems is, of course, in the peripherals, which are shared by all the LIS work stations; thus the system becomes even more cost effective as it grows. Every device depicted, with the exception of the communication interface, is an off-the-shelf item. All the interactive work is done at the work station in conjunction with a refresh-type CRT, keyboards, and the Gradicon digitizer. The CRT's are 15 to 17 in with 1,024-point resolution on each axis.

The work station configuration is shown in figure 2. The CRT is mounted on the digitizer controller, which is on wheels for moving with the operator. The digitizer cursor and the keyboards are free floating so that they can be placed anywhere on the table. The PDS-1G minicomputer could actually be installed under the table or in a variety of other places. The digitizing table is capable of resolutions on the order of 10 μm, although in practice the resolutions were never chosen exceeding 20 μm. With resolutions of 20 μm and sampling distances of 40 μm, smoothness of even the smallest radius curves was guaranteed, and class A cartographic standards were more than met.

However this is a session on editing, and this presentation is partly a discussion of how LIS provides the cartographer; in an interactive fashion with a highly effective, precision editing mechanism as good as the data being captured, i.e., 20-μm resolution and 40-μm sampling distance. These distances are smaller than the eye can resolve without optical aids. Thus if the high standards of data capture are to be maintained, the editing system must provide significant help to the cartographer.

Figure 3 illustrates the basic editing functions that are involved in correcting digitization errors, both as-you-go and later. Six types of edit are shown, although in reality only 5 basic operations are involved:

- -End-segment modify (encompasses extend-segment and delete-segment operations)
- -Mid-segment modify (or modify segment)
- -Joining features
- -Deleting features
- -Adding features

As an example, you will now go through the motions of a mid-segment modify operation. Figure 4 is a problem case where a coastline has had a landslide; the solid line is the coastline before the landslide, and the dotted line is the coastline after the landslide. The slide is labeled "Mid-Segment Modify" as it appears on the work-station CRT. The actual image size on the screen can be visualized by assuming a 17-in diagonal to the image.

First (fig. 5), the cartographer moves the digitizer cursor to a position in proximity to the point where he wishes to begin editing. He signals LIS his position by depressing one of the buttons on the

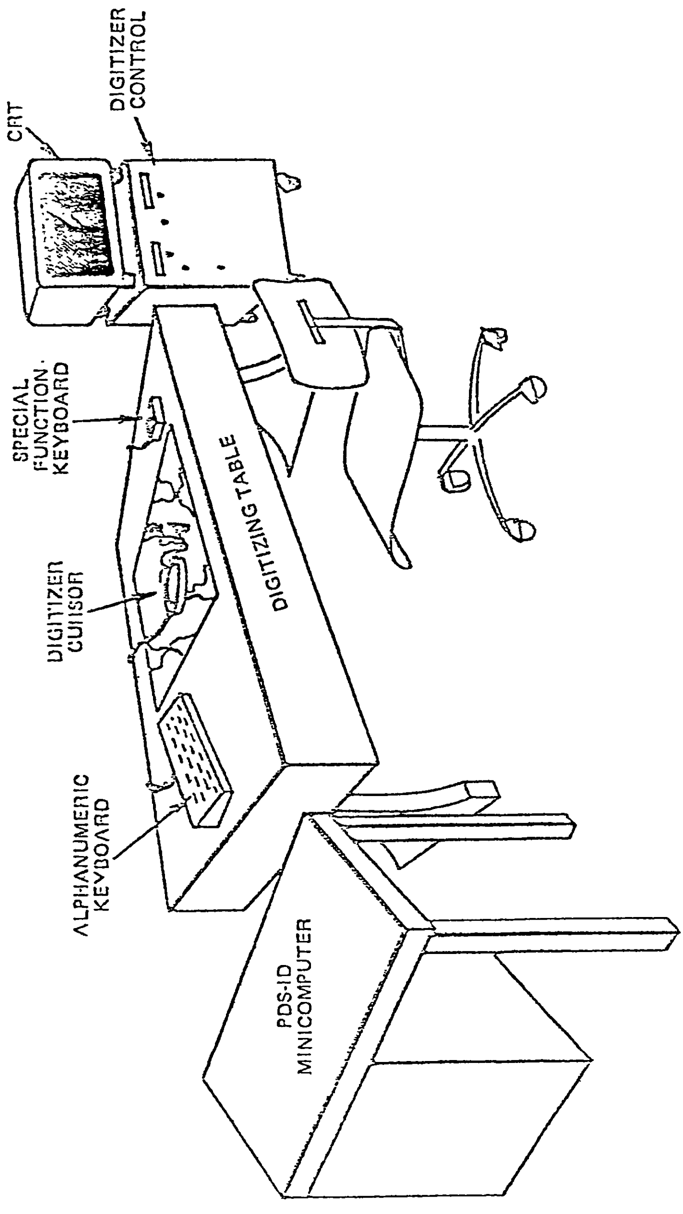

CRT
DIGITIZER CONTROL
SPECIAL FUNCTION KEYBOARD
DIGITIZER CURSOR
DIGITIZING TABLE
ALPHANUMERIC KEYBOARD
PDS-ID MINICOMPUTER

Figure 2

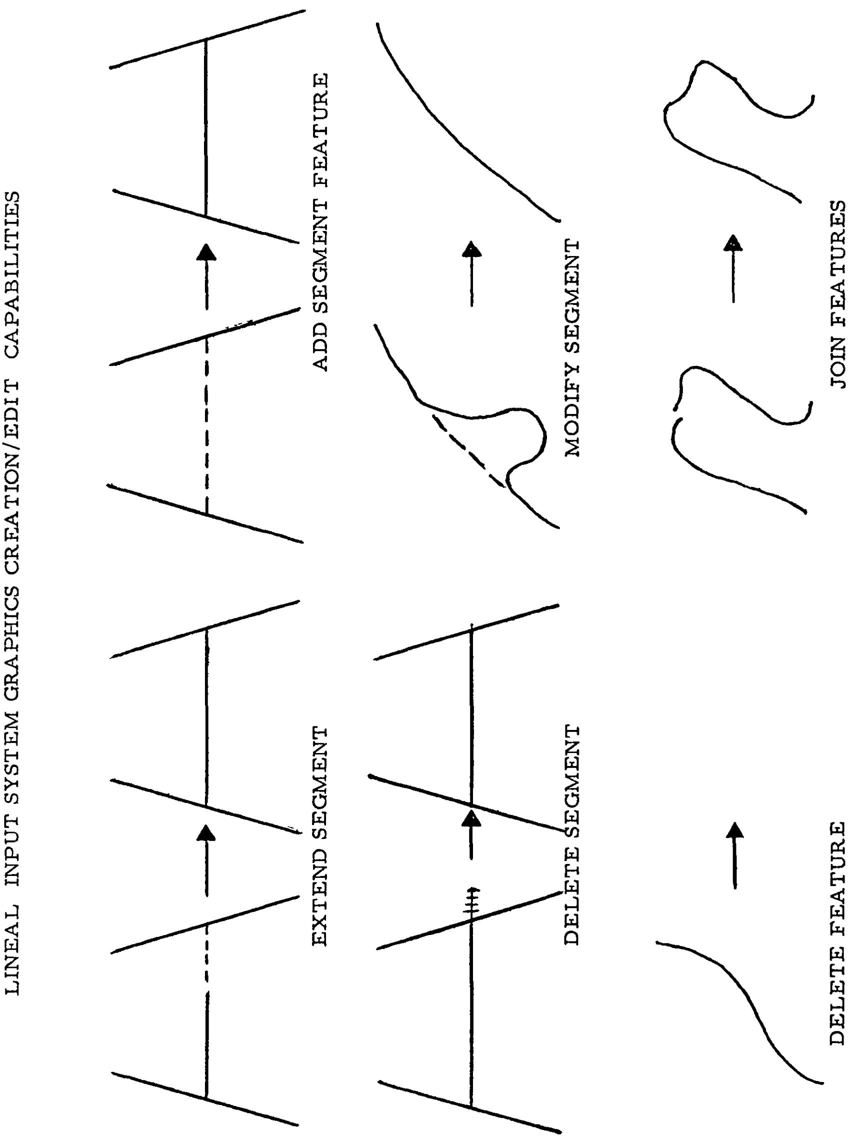
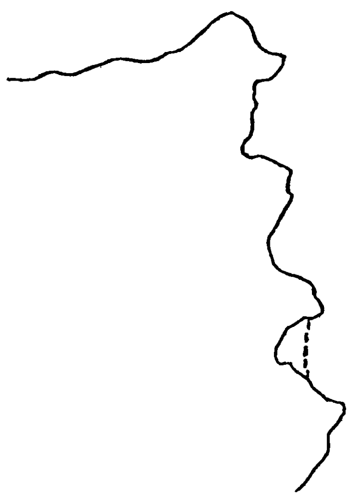
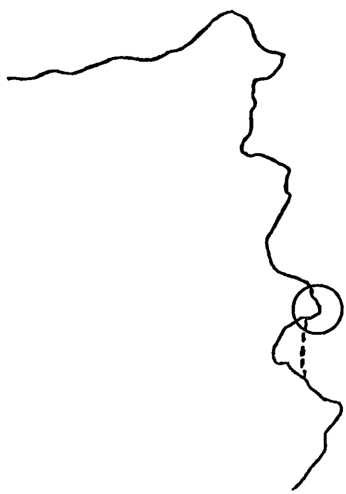

LINEAL INPUT SYSTEM GRAPHICS CREATION/EDIT CAPABILITIES
EXTEND SEGMENT
ADD SEGMENT FEATURE
DELETE SEGMENT
MODIFY SEGMENT
DELETE FEATURE
JOIN FEATURES

Figure 3



Mid Segment Modify

Figure 4



Mid Segment Modify

Figure 5

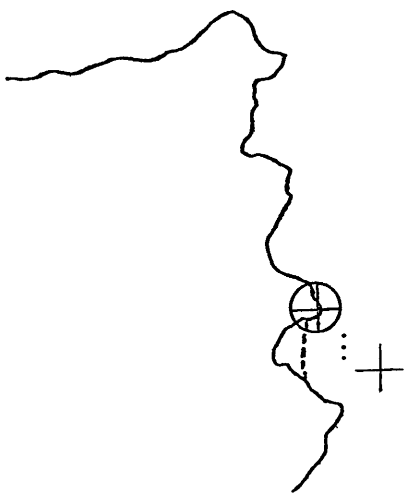
cursor, and the system responds by circling the specified point, or nearest feature point, on the screen. Thus the cursor does not have to be positioned exactly on the edit point, but need only come within eyeball precision. At this point, the cartographer accepts or rejects the circle. If rejected, the cartographer can reposition the digitizing cursor to a new location and get a new circle. Eventually the cartographer accepts the circle location and presses another button.

The system then responds by placing a crosshair on the screen (fig. 6) which is linked to the position of the digitizer stylus, that is, moving the stylus moves the crosshair on the screen. Now the critical point: How does the cartographer position the stylus so that the resulting edit will not have any slope discontinuity or jaggedness? In LIS, the cartographer places the crosshairs in the circle; gun-sighting the stylus, a smooth, continuous line or join at the edit point is guaranteed. In practice, the cartographer can place the stylus within 2 resolution units of the actual feature position; with this closure, a special LIS software routine makes a smooth join with the old feature.

Figure 7 shows the result. The cartographer has locked onto the old feature and drawn what is now the solid line. The stylus is brought close to the other end of the edit and the CRT verifies that the smoothing algorithm can indeed be used. Upon seeing the results, the cartographer then either accepts or rejects the edit and repeats the process until satisfied.

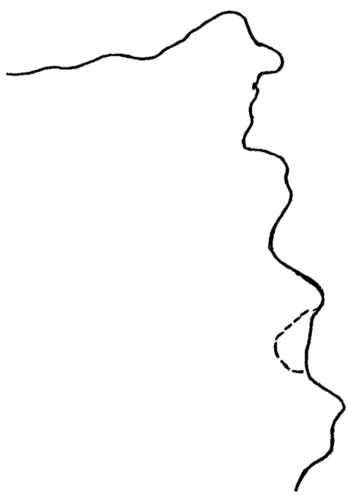
As important and time consuming as interactive editing of lineal features is, there is another type of editing that was developed for RADC with LIS and other systems. This is automated editing--those types of editing that don't require a human being because they don't require intelligence and judgment, just a lot of processing, smoothing, cleaning. One typical example of automated editing on the Remote Job Entry System is the clip/join illustrated in figure 8. We all know that it can take many minutes to try for an absolutely clean join of two lines and many more minutes to verify that all such conditions requiring joining have been identified by the cartographer and corrected. Wouldn't it be so much nicer if the cartographer, in digitizing and editing the features, only had to get within eyeball accuracy so that he could let the machinery clean it up for perfect clips or joins. This is exactly the technique that is employed at the Experimental Cartographic Facility and is incorporated into both the Batch Processing System and LIS.

I'd like to say a few words about a secondary but very important area in the field of cartographic editing. In existing systems to a large degree, lineal data are involved. Thus we are discussing the ability to enter lineal data either manually with a digitizing device or semiautomatically with things such as automatic line following equipment like that currently being developed at RADC. There is an alternative to lineal data and that is raster data. Raster data become especially important to people who have to rapidly develop a very large data base of cartographic information; classical lineal digitizing is just too slow. Enter--the automatic scan device.



Mid Segment Modify

Figure 6



Accept/Reject

Figure 7

Clipping/Joining Function

Description

The clipping/joining module functions to effect a clipping or joining action on adjacent digital features generated at the digitizing station. Digital clipping or joining is necessitated by inadvertant overruns or underruns, respectively, when the end point of one feature is in common with an intermediate point of another feature. Clipping involves the deletion of points produced as a result of a feature overrun. Joining involves the addition of points to a feature in order to close the digital gap produced by an underrun.

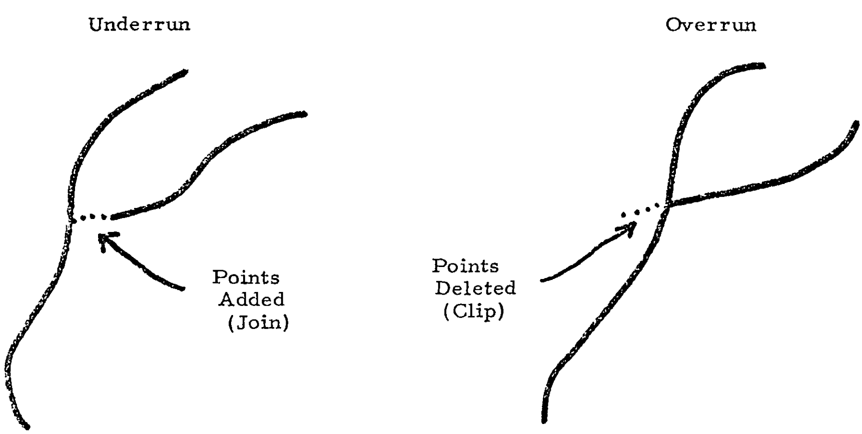



Figure 8

The automatic color scanning device (ACSD) has been available at RADC for several years. The output is raster data organized by x-y position rather than by features in the x-y field. It is easy to assume that the raster form is not readily usable for many cartographic processes, specifically those such as line symbolization and feature identification. These two processes are closely allied with the presentation of information on a chart in a form that is readily interpretable by the human user. For this type of operation, lineal organization now appears to be the best method. Thus we must resolve the problem of transferring the raster data obtained by the scanning device to a lineal format. This conversion really involves two steps: (1) a pre-edit function for cleaning up noise and machine-detection errors, and (2) the actual conversion. Keeping to edit problems, I will completely bypass the raster-to-lineal conversion problem.

The company recently installed an interactive CRT-oriented edit system for raster data--the Raster Edit System (RES)--at RADC. Here we work with the raw data from the scanning device and use a Tektronix storage tube display to handle the large density of line work. The RES design provides for looking at either a large part of the manuscript or for blowing up a specified window within the manuscript to look at smaller areas. Zooming can get down to individual points and lines where the human can identify noise from clean data and take editing steps. Noise can take the place of unwanted or missing points. Effectively a man using his associative eyeball can go in and find those dirty areas where he expects problems for any raster to lineal conversion software or where he expects problems will arise in later processing. Thus RES adds the intuitive, associative human brain to the interactive environment in providing an editing function on raw raster data.

<u>Schuler (Control Data Corp.)</u>: Could you possibly give us a handle on the timing associated with your automatic editing and identify the computer?

<u>Moritz</u>: The biggest machine in figure 1 has 32-k word core. That machine is shared by up to 10 8-k word minicomputers. In these PDS-1G minicomputers all the graphics work is done right there. There is no need to call on the main or master processor for anything other than data through its data management system. All the editing operations are literally interactive, online, and real time or very nearly real time. From the time a man selects a feature to be edited by simply pointing the cursor on the graphic, our experience is that it never takes longer than 3 sec to retrieve the feature with 5 stations operational.

<u>Schuler</u>: I am referring more to the automatic editing where you have an overflow or an underflow problem at a join.

<u>Moritz</u>: We can take a typical file of several thousand inches, and it will run anywhere up to 5 or 6 min on a PDP-15 in a time-shared environment. It is fairly fast.

Rockwell (Dept. of Community Affairs): It is the conviction of the entire panel that the only way you can work with interactive editing is to create a new data base which is not the same as the data base you are ultimately going to have to be doing your analyses on? In other words, if you want to go back and correct something that existed before, there seems to be a need to pull it out of one data base format and put it into a new one. Is this something that we are never going to be able to get around? Can we ever work right on the data that we want to do our analyses on?

Moritz: I can speak in terms of how long it takes to do data transformations on individual points. It is theoretically possible, knowing all the connections between a variety of different coordinate systems, that you could always convert on the fly. Again, we are running into a cost situation. Given a parallel processor, perhaps, or a machine that operates at 10 to 100 times the current speed, you might be able to do such things. Take a look at CIA, for example, which requires a geographic global basis for a data base. This means geographic coordinates--latitude and longitude--or if you want to set up some form of Earth meter system, that's okay too. Here you are talking about taking a variety of scales--1:1,000, 1:50,0000, 1:100,000, 1:1,000,000, 1:3,000,000--and a variety of different projections--Mercator, transverse Mercator, Lambert conformal, and so on and being able to match or merge them together to give yourself a standard reference frame through which everything can be correlated. If you do not require it, there is no need to do this on a global basis; then there is no problem.

Rockwell: So the kinds of constraints that have been discussed so far in the hardware session are tied to the needs to meet National Map Accuracy Standards and that kind of thing. If you are working in a purely analytic framework, (as an analytic geographer would) and you were interested in 1-percent accuracy, the whole game becomes dramatically simpler.

Moritz: It could be; I think that it is too easy to answer yes or no. I would have to know more or less what the application is.

Peucker (Simon Fraser Univ.): I have a general comment. I don't think that we will ever have clean data. We might have accurate data or smooth data; we might have all kinds of other things, but clean is a dirty word. I will give you an example. The CIA has digitized the east coast of Australia. They have run it through their system, and for them it is clean. An Australian looks at it and doesn't find the Bay of Brisbane--for him it is not clean and of no use at all.

Moritz: Quickly, I want to point out that right now the existing systems are using coordinate frames which are better than .01 sec of arc. Granted, if you want to get less than a foot or two on the Earth's surface, then you might run into nonclean conditions. Everything that we have been able to work with to date on the systems at DMA-AC and HC is good to that type of resolution.

Chrisman: I am not here to speak in favor of the DIME system, but I think it should be brought up right now. We have been talking about people; we have been talking about interactive editing and some automatic editing. There has been a lot of U.S. money spent on systems for automatic clarification of what is effectively geographic representation--money spent by the Bureau of the Census on the DIME system. None of you mentioned any of that. It seems important to me that there is no interaction between the people who are trying to model urban systems at less-than-cartographic accuracy, and people who are trying to model cartographic information very accurately. There is a block somewhere between the two groups. I think that there should be more realization by cartographers that there is actually something to that form of editing. And I think that there is a need for the DIME people to be more aware of what is cartographically available to them. That is not something for this workshop. We do have people who are supposed to be here from Census sometime later; I am trying to present their case temporarily.

Aangeenbrug (Bureau of the Census): I am currently looking at the DIME file, and there will be a demonstration (twice) in seminar form where these topics will be discussed. I agree with the comment, having been a victim and a visitor at the USBC project, that there are problems in terms of dealing with absolute and relative accuracy. Going back to some of my lectures with Prof. Robinson, we are not shooting missles into urban areas, so the absolute accuracy is not that important. You get into a policy question here. I think that we might try to take advantage of the DIME seminar to address some of these points. Perhaps at a later session, we might want to discuss the needs for absolute and relative accuracy, because there is a big world of dirty cartography that gets most of the people to work daily, that caused presidents to make decisions, and so forth. Those are now becoming automated, so I urge us to discuss these later.

Rhind: I would just like to make a point that there appears to be a paradox in much of this work that cartography, which has high-accuracy requirements in some cases, needs much less carefully edited data than does certain geographical processing. If a small segment of line is missing in a map file, then it can be put in by pen--a semiautomated process. On the other hand, if a small segment of line is missing in card-fitting areas, then you have a real problem indeed if it is all being done inside the machine.

Boyle: When we were talking about drafting systems, I said that I believed it is in a professional state. If you want high-precision drafting, it is a professional job which should not be attacked by people on their own. As an exact opposite of that, I believe that everyone should have an interactive viewing and editing capability. I believe that this is their driving tool--to see what they have. If they are going to have digital data, they should be able to look at it and to play with it. The cost of these things is not very high relative to precision drafting and digitizing. You notice that it was very difficult for the last speakers to separate digitization--certainly interactive manual digitization--and interactive editing; one flows into the other.

Many people have tried to do their own digitization work over the last 10 yr or more. If they have bought any equipment at all, they have bought digitizing equipment. Many many people have ended up with rooms full of punched tape. Except for a few who have attacked it professionally, most of the people have been playing at digitization. Just about now it appears to me that we are moving into the professional stage of digitization, in which the work can be done reliably, predictably, and so on. We tried to bring some of these people together to tell you about the state of the art. I do not think that we are at the point where we just put out a contract, pay x thousands of dollars, and obtain the map data perfectly done. However, I think we are very near that.

You will want to update some of the digitized data without sending it out to some massive drum scanner, automatic line follower, or whatever. You will want to do this a little bit more accurately than you can eyeball on the display screen. A personal editing facility, in my view, is an interactive display with a part-time digitizing table connected to it. I am going to ask Olin Bockes to come up now and bring his panel with him. Bockes has been involved with the Forest Service in the Department of Agriculture for many years and has recently changed his allegiance to the Soil Conservation Service.

## Input Methods Panel

Olin Bockes, Presiding
Soil Conservation Service

Dan G. Dixon
DMA Hydrographic Center

Hollis F. Ryan
Calspan Corp.

James O. McDonough
Concord Control Inc.

Peter G. Wohlmut
i/o Metrics

Bockes: As Dr. Boyle said this morning, the structure of this session has been designed to present the current state of the art. "Current", perhaps, depends on where you are in the cycle. If you are a researcher in a university environment where the community is a highly technical, specialized group of people, "current" means one thing. If you operate in a production shop, current technology is a different world, and the people who are working with that technology are a different group of people. I would like to think that everyone, whether in research and development or in production-oriented programs, is as far along as Dr. Boyle suggested. I would like to believe that we are going to have current problems in automated drafting solved in a year or so.

I suspect that our first speaker from "production" will not be quite this optimistic. He is Dan Dixon, a scientific staff assistant at DMA Hydrographic Center. The last panel discussed the LIS system, and Dan is involved in planning and coordinating the implementation, production, and utilization of that system. After Dan, we will hear about some of the newer scanner systems. Panel member Hollis Ryan is from CALSPAN Corp. in Buffalo, N.Y., formerly the Cornell Aeronautical Laboratories. CALSPAN has dealt in image processing for many years and has expanded to line encoding, fingerprint identification, and that sort of work. We also have Jim McDonough from Concord Control and Peter Wohlmut from i/o Metrics, where digitizing by tracking small automic particals was developed.

I think we have come a long way from 5 yr ago when we were talking about etched grooves on metal plates, inertial problems with floating-arm digitizing, and designs for cursors that would facilitate observing, tagging, and locating points.

Dixon: The Defense Mapping Agency Hydrographic Center (DMAHC) may not be exactly a household word to many of you. When DMA was formed several years ago, we were a split off from the Naval Oceanographic Office which at that time had the responsibility for hydrographic charting and mapping, along with various oceanographic functions. Essentially our function is to provide hydrographic charts, publications, and other related products to support both the maritime and naval fleets. This support is provided on a worldwide basis with the exception of those areas encompassing the continental U.S. and its possessions which fall under the cognizance of the National Ocean Survey.

The expansion in the automated cartography program at DMAHC began last year with the acquisition of the Lineal Input System (LIS) which was developed by the Rome Air Development Center under contract to the Planning Research Corp. (PRC). Although LIS represents the first "advanced" equipment for our automated cartographic system, high-precision digital plotting equipment has been in use at DMAHC since the mid 1960's.

Figure 1 illustrates the DMAHC Automated Cartographic System basic functions: data acquisition which LIS currently satisfies; the hydrocartographic data bank, a separate entity; data exploitation which would include the device that Howard Carr mentioned previously--the DIODE or digital input/output display equipment; and graphic finishing which includes various types of high-precision plotting devices, including raster and standard x-y vector plotters. LIS has been on board a year in which a comprehensive 6-mo test and evaluation program was completed including processing actual chart data.

Figure 2 shows the LIS equipment arrangement. This is a typical layout for a work station interfaced to the master processor PDP-15. On the far right is the offline Xynetics proofing plotter. A typical work station includes a Gradicon digitizer interfaced to an Imlac PDS-1G interactive graphics display. The Imlac display shown here is actually mounted on a stand located at one end of the digitizing table. The various work stations function under control of the master processor through a time-sharing arrangement. As various routines are called for via Imlac keyboard interaction, software modules are transmitted from mass storage to the Imlac minicomputer.

This provides for more effective utilization of system processing and data storage/retrieval capabilities, accommodating up to 10 work stations for a single master processor. There are four digitizing work stations now operational; one will be added in Jan. 1975; and five more are tentatively scheduled for acquisition during the next 12 to 16 months.

Figure 3 depicts the present LIS configuration for 4 work stations all served by the PDP-15 master processor. Peripherals include 2 fixed-head disks, 2 disk-pack drives, and other standard peripherals. The Xynetics plotter operates offline and performs quite satisfactorily in generating proof plots of LIS data for editing purposes; it is an extremely high-speed plotter, as fast as 40 in/sec with an overal accuracy of 0.0045 in.

Figure 4 is a shot of the master processor with the disk-pack drives in the middle background and the deck tape units on the far right.

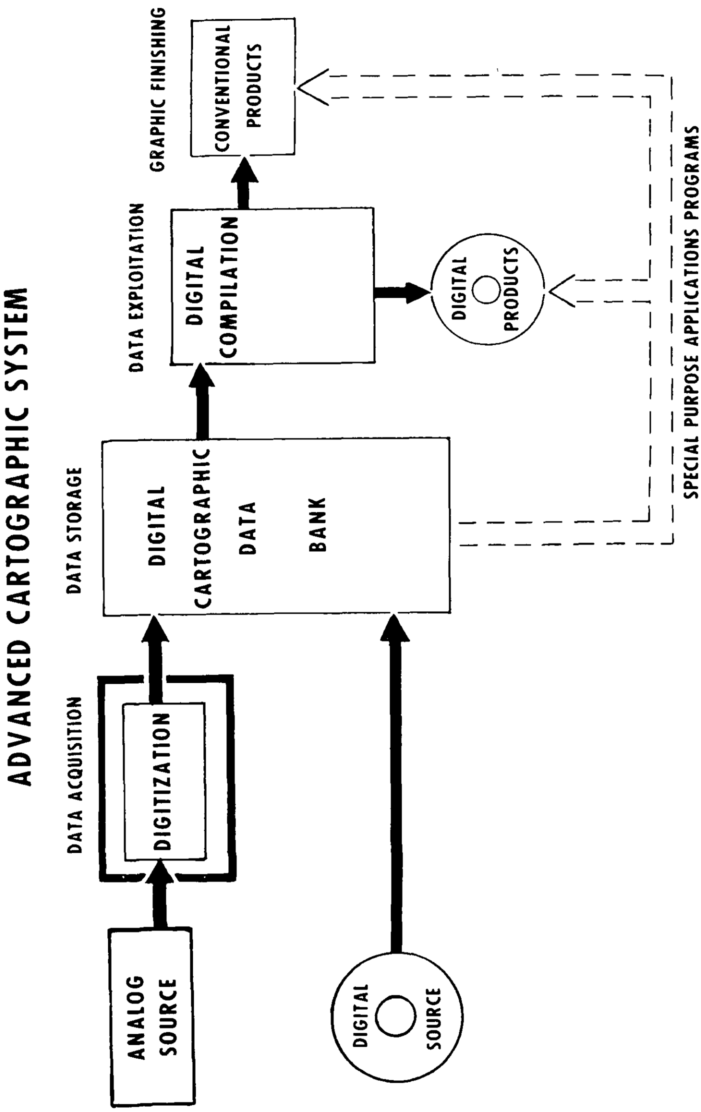

ADVANCED CARTOGRAPHIC SYSTEM
DATA ACQUISITION
DATA STORAGE
DATA EXPLOITATION
GRAPHIC FINISHING
ANALOG SOURCE
DIGITIZATION
DIGITAL SOURCE
DIGITAL CARTOGRAPHIC DATA BANK
DIGITAL COMPILATION
DIGITAL PRODUCTS
CONVENTIONAL PRODUCTS
SPECIAL PURPOSE APPLICATIONS PROGRAMS

Figure 1

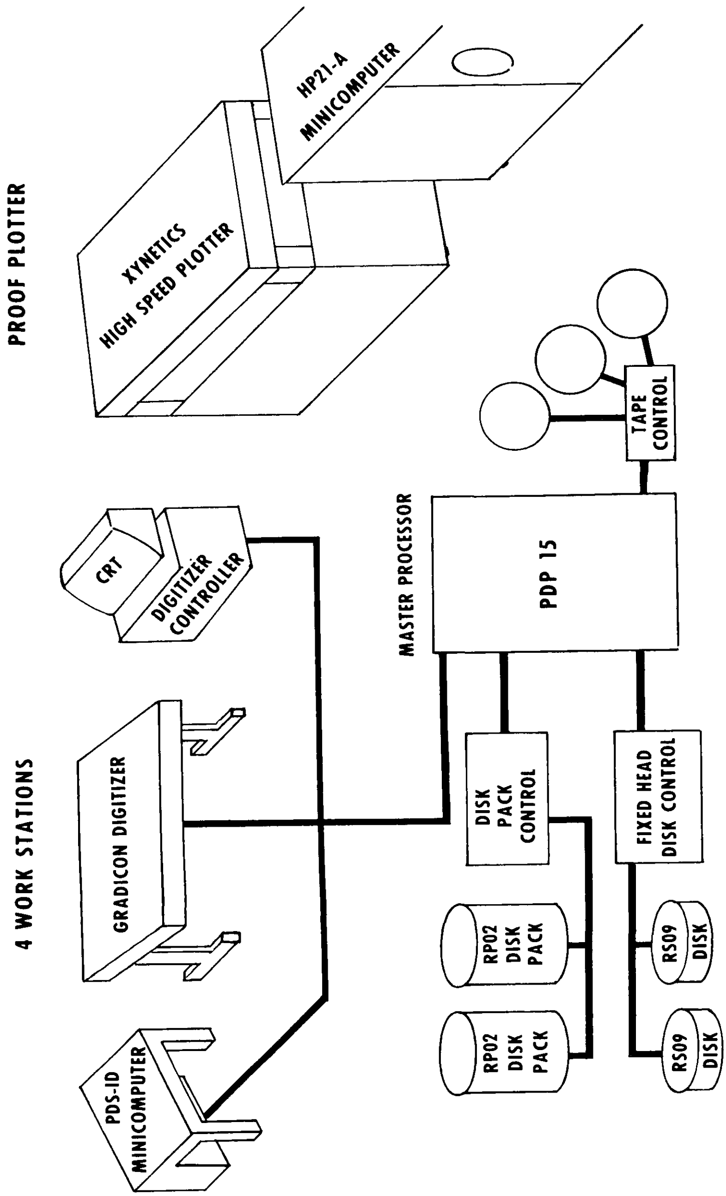

PROOF PLOTTER
XYNETICS
HIGH SPEED PLOTTER
HP21-A
MINICOMPUTER
TAPE
CONTROL
MASTER PROCESSOR
PDP 15
CRT
DIGITIZER
CONTROLLER
4 WORK STATIONS
GRADICON DIGITIZER
PDS-ID
MINICOMPUTER
DISK
PACK
CONTROL
FIXED HEAD
DISK CONTROL
RP02
DISK
PACK
RP02
DISK
PACK
RS09
DISK
RS09
DISK

Figure 2

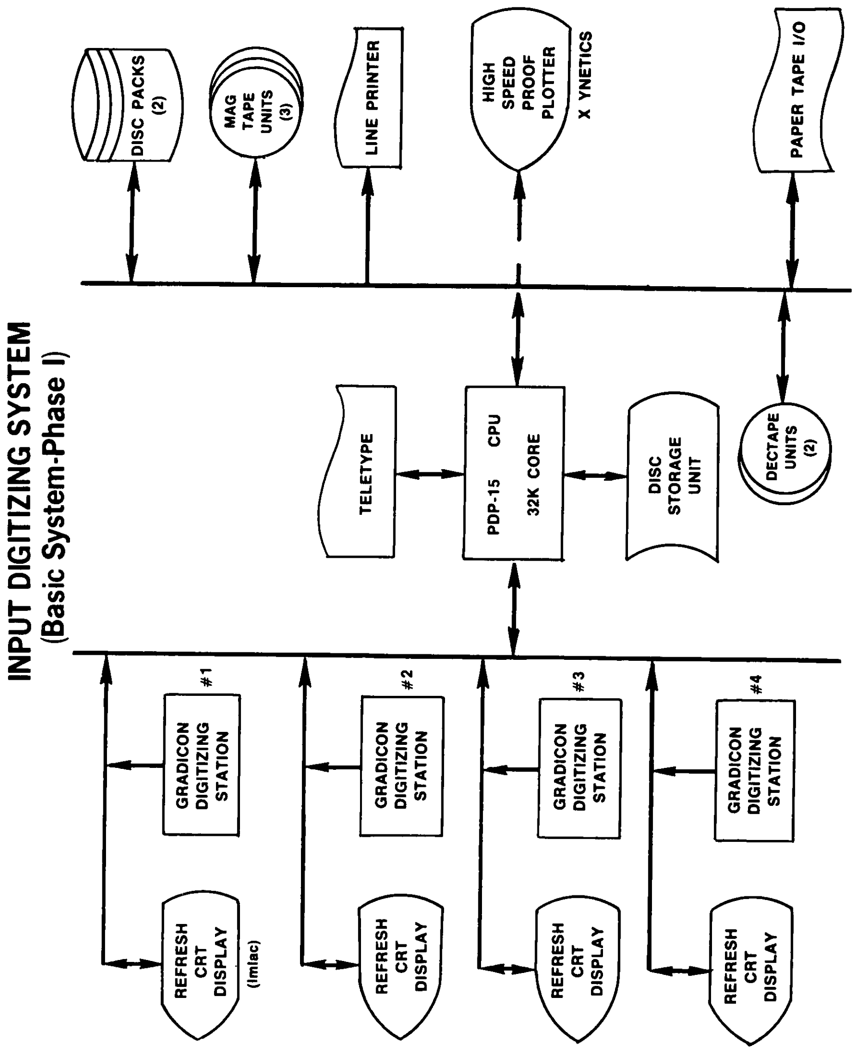

INPUT DIGITIZING SYSTEM
(Basic System-Phase I)
DISC PACKS (2)
MAG TAPE UNITS (3)
LINE PRINTER
HIGH SPEED PROOF PLOTTER
X YNETICS
PAPER TAPE I/O
TELETYPE
PDP-15 CPU
32K CORE
DISC STORAGE UNIT
DECTAPE UNITS (2)
GRADICON DIGITIZING STATION #1
REFRESH CRT DISPLAY (Imlac)
GRADICON DIGITIZING STATION #2
REFRESH CRT DISPLAY
GRADICON DIGITIZING STATION #3
REFRESH CRT DISPLAY
GRADICON DIGITIZING STATION #4
REFRESH CRT DISPLAY

Figure 3

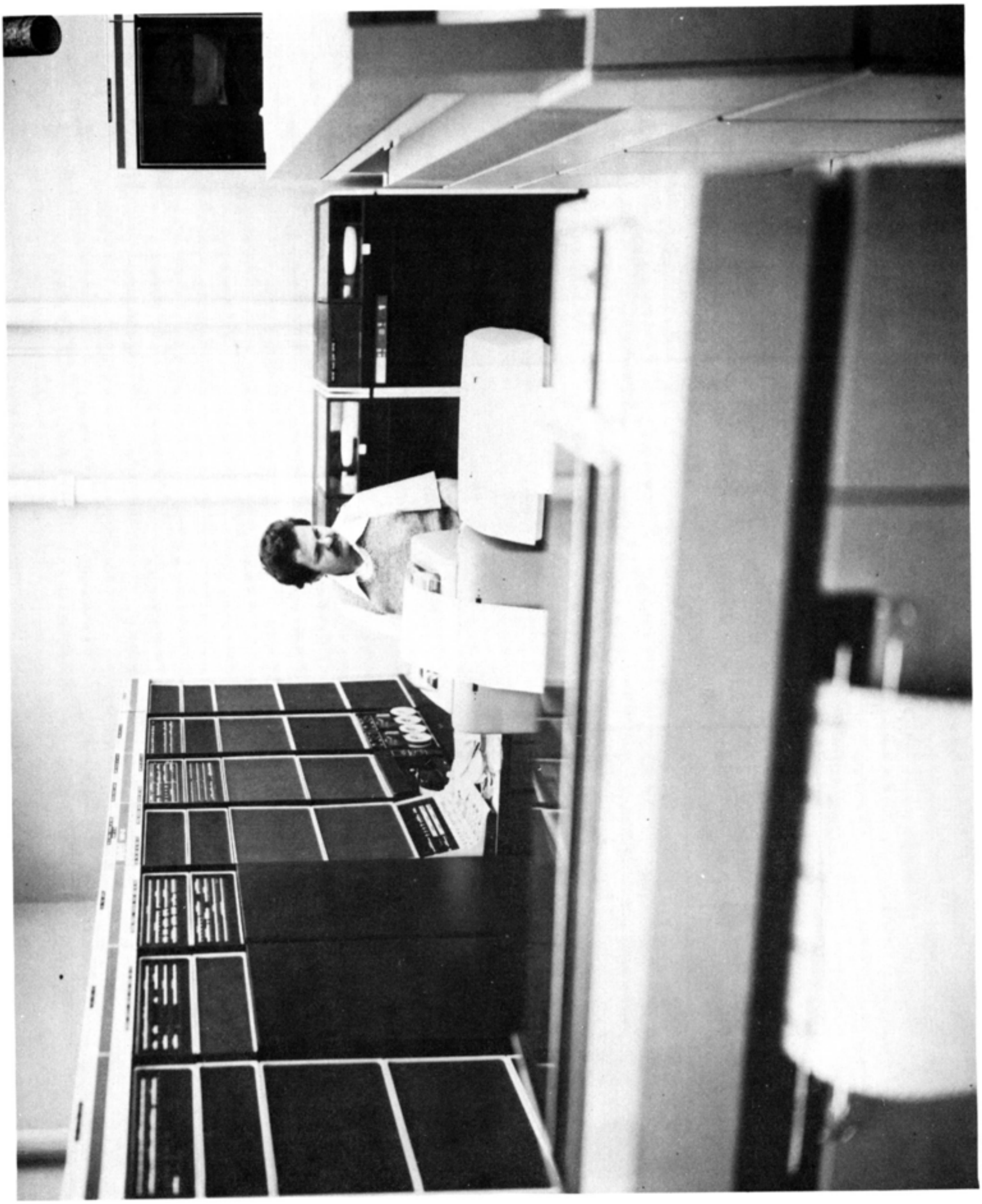


Figure 4

The Xynetics plotter (fig. 5) satisfies the edit/plot-generation function. It is controlled by a Hewlett-Packard 2100 minicomputer with 8-k core which provides significant plot-generation capability for other applications. The plotter is used to generate a number of other interim products such as bathymetric data collection sheets to contain depth or sounding information amounting to 8 k or 9 k values/sheet. Previously, these sheets were generated much slower with a CalComp plotter.

Figure 6 presents a closeup of a work station. Normally, the cartographer performs various functions (create file, file registration, digitize, edit, remote job-entry processing) through sequential responses to queries presented on the display screen. The first procedure (create file) entails entering, via the keyboard, various parameters describing the source to be digitized. When completed, the cartographer would register the new file to the source sheet secured to the digitizing table. At this point, the cartographer could enter the digitization mode and would be presented a list of feature types via the display from which to make a selection.

Figure 7 presents the selection of functions. In order to digitize, the cartographer would punch the number "3". However, before digitizing, the feature must be properly identified or "headered." The cartographer must proceed through a header building scheme in which data would be entered into blank fields for feature class, type, subtype, and 8 associated levels of descriptors. For example, a typical header description for a buoy would include the color, flashing frequency, and ID number. When data bank retrieval and maintenance procedures are fully considered, I think it is essential that a significant description be provided for each feature being digitized for data bank retention and future utilization.

After 2 to 4 hr of digitizing, the cartographer would generate a tape of the digital data and then obtain a Xynetics plot. The cartographer would then register the plot to the source material and identify any discrepancies that might exist. When completed, the cartographer could then select any of the edit procedures available (fig.8) to correct the glitches. These corrections could include deleting a feature, changing the midsection of a feature, or changing the feature header. I sometimes like to refer to this system as "cartographer-proof." Although I don't particularly care for the term, it does relate the significant amount of built-in safeguards. Considering the complexity of the operations of sophisticated systems such as LIS, I don't feel that the safeguards represent needless "over-engineering" at this point. Once we become more familiar with automated operations, I personally feel that many of the safeguards can be eliminated, alleviating many redundant and time-consuming procedures. But for the time being, the present level of system safeguarding is considered necessary.

Once editing has been completed and all changes made, the operator would select a remote job-entry processing routine (fig. 9) for the desired reference frame, such as geographic coordinates. LIS is based on the storage of data by geographic coordinates. The

Figure 5

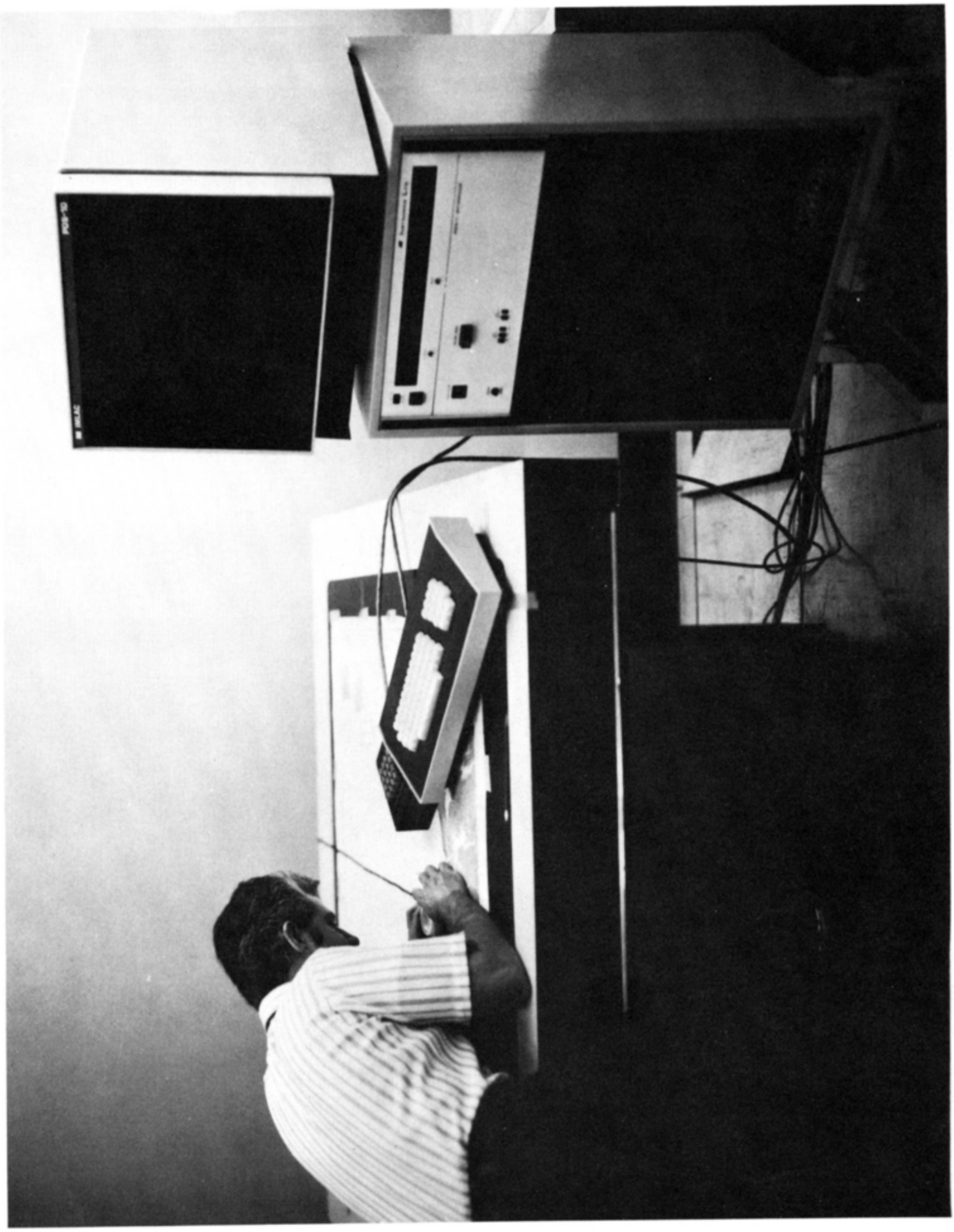


Figure 6

# MASTER MODE

1 CREATE FILE

2 REGISTER

3 DIGITIZE

4 EDIT

5 REMOTE JOB ENTRY

6 LOG OFF

ENTER SELECTION NUMBER 3

Figure 7

# SPECIAL FUNCTION KEYBOARD

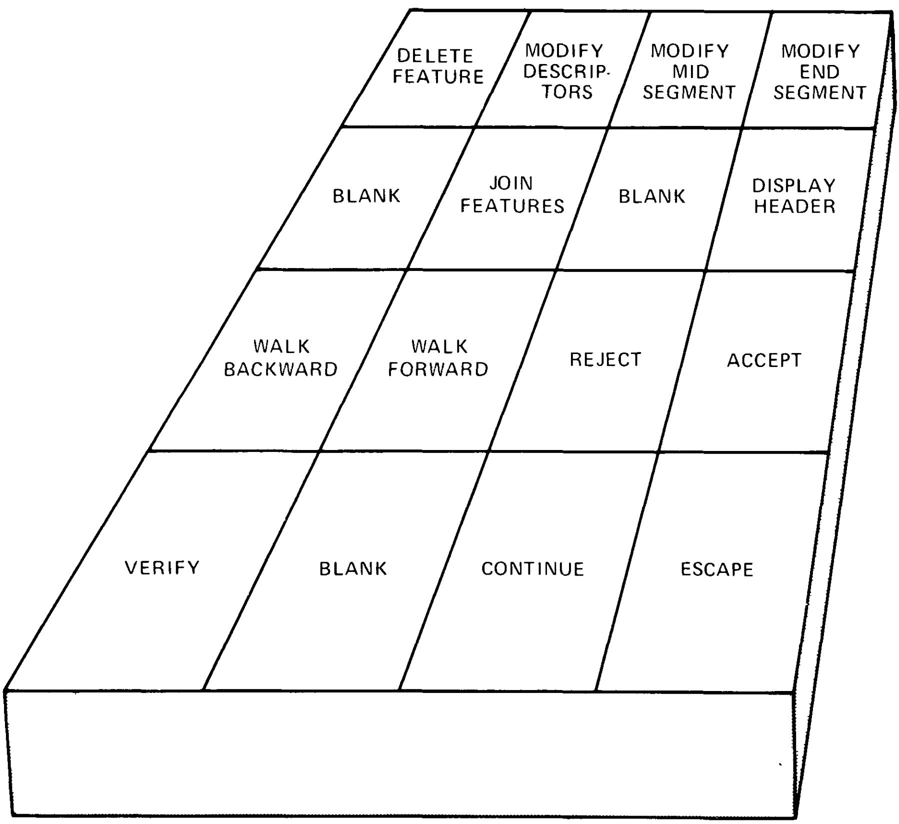



Figure 8

# RJE
# REMOTE TASK SELECTION

| | |
|---|---|
| 1 | INPUT FROM A MAGNETIC TAPE |
| 2 | OUTPUT TO A MAGNETIC TAPE |
| 3 | TRANSFORM TO GEOGRAPHICS |
| 4 | PLOT |
| 5 | SECTION GEOGRAPHIC |
| 6 | SECTION TABLE |
| 7 | CLIP/JOIN |
| 10 | PANEL |
| 11 | END OF JOB |
| 12 | CANCEL JOB |

ENTER SELECTION NUMBER

Figure 9

type of data that we are producing with LIS essentially addresses production of two distinctly different items--hard copy and digital products (digital data bases and digital charts). LIS actually provides input to the digital compilation process from which final hard copy is generated. On the other hand, LIS is the primary system from which final digital products will be developed.

LIS is now being used primarily to generate a special-purpose digital data base for the Norfolk, Va., area (fig. 10). Data are being extracted from about 80 charts and maps--70 USGS maps at 1:24,000 scale and 10 NOS charts ranging from 1:20,000 to 1:40,000 scale. Culture, shoreline, and topography are being extracted from the USGS maps, and the NOS charts provide navigational information.

Some rather interesting problems have been encountered. It had been decided that shoreline would be derived from 1:20,000-scale NOS charts and matched with culture and contours from the USGS maps. I am not sure what happened, but when the chart was reduced to 1:24,000 and layed over the contour and culture plots appropriately scaled from the maps, the shoreline did not fit the contours and culture. Roads that were supposed to intersect the middle of piers were in the water along with a number of contours. This is not to say that the NOS charts were less accurate than the USGS maps or vice versa. I think what really happened was that the degree of generalization by the cartographers might have differed enough to result in distinctly different products, and I feel this is not going to be the last time that we will encounter the problem.

As I said, we are presently producing a digital data base with LIS; however, during the next fiscal year data will be digitized to produce special-purpose, small-scale, fleet-oriented graphics. We do not have full capability required, but are aiming for standard nautical chart production. The graphic finishing process alone is a monumental task, particularly automated symbolization for a wide variety of features. Within the next 2 or 3 yr of R&D efforts with Engineering Topographic Laboratories and Rome Air Development Center, we should see significant progress. The ultimate goal is to automate the entire chart production and maintenance program, and we have taken the first steps.

Ryan: I would like to describe how image processing technology has been applied to the digitizing operation. As specialists in image processing, we saw that our techniques could be applied to the map digitizing problem.

Figure 1 lists some applications of image processing technology related to map digitizing. More specifically we have applied the technique of developing algorithms using interactive minicomputer techniques, the image processing algorithms themselves, and the digital hardware implementation technology. There are two programs that I will describe. One refers to the first application, called SEASCAPE, and is being used by the Office of Naval Research for digitizing bathymetry charts. The other program, called DIGIMAP, is being developed on company funds to provide the service of digitizing charts and manipulating the encoded data; the most important manipulation is computer-compositing map sheets.

# GEOGRAPHICAL TEST AREA FOR PROTOTYPE NTEC SHIPBOARD RADAR NAVIGATION TRAINER SIMULATOR

**LEGEND**

AREA-4096 SQ. N.M.
LOCATION-NORFOLK VA. AREA
BASE SCALE-1:24,000
BASIC SOURCE-USGS 7½
MINUTE QUAD SHEETS
NOS HARBOR CHARTS
RADAR SCOPE PHOTOGRAPHY
RECORDING RESOLUTION-40 MICRONS
GROUND RESOLUTION-1½ METERS AT 1:25,000

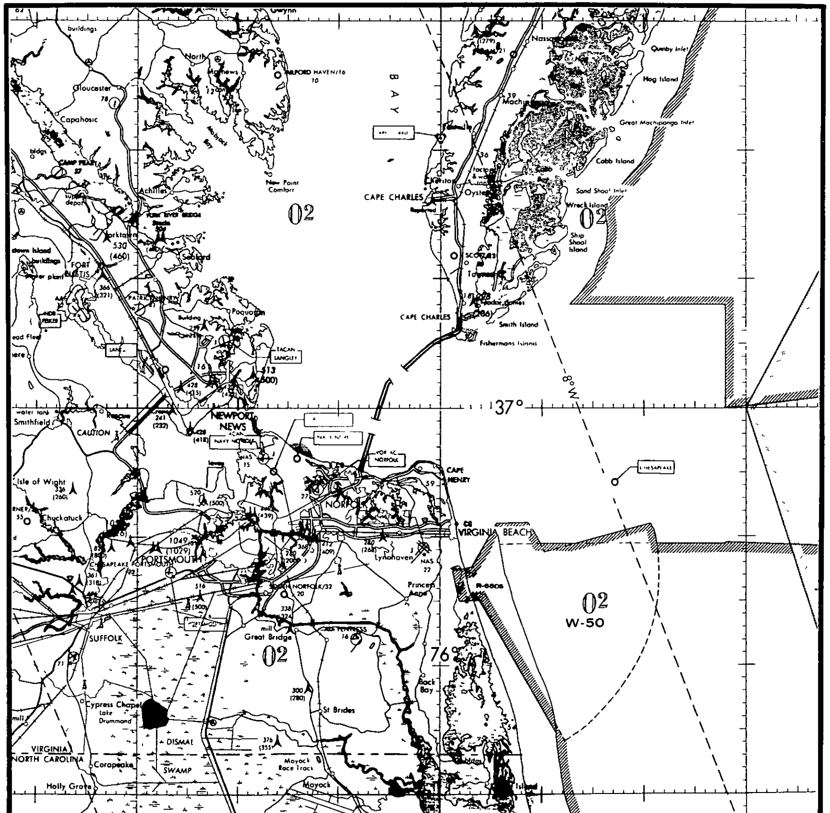



Figure 10

# EXPERIENCE IN IMAGE PROCESSING

- DIGITIZING BATHYMETRY CHARTS
- DIGITIZING BLUEPRINTS
- PARTICLE COUNTING
- FINGERPRINT READING

Figure 1

Figure 2 is a picture of our image processing facility for digitizing the bathymetry charts. This digitizing program started 3 yr ago this December, and production started a year ago last July. So far 350 charts have been digitized and there are several hundred more.

The Navy digitizing system consists of a set of computer programs that run on a PDP-9 minicomputer (right side of fig. 2) The input is provided by a flying-spot scanner (background of fig. 2). The maps are photographed onto 70 mm film which is placed on a film transport inside the scanner. The digitizing is done frame by frame. The system was tailored to meet the needs of the Navy. Every point on the depth contours is not digitized, only selected points to form a grid of depths which is processed by a spline interpolation program to generate a uniform grid of depth data.

This system is an example of an application in which cartographic accuracy is not needed nor obtained. Sampling the depth information and then interpolating reduces the accuracy of the original data. Image processing techniques are used to automatically detect the location of a depth contour on the map and to follow it. The lines are followed not to encode them, but to carry forward the depth information from the last encoded point, thus eliminating the need for an operator to enter depth information again at the new point. This is an interactive system and the operator has considerable editing capability. This is a requirement for the system because the charts that we are working with, from the image processing point of view, are of poor quality; for example, frequently sections of lines will drop out when we scan the map image and transfer it to the computer for processing.

Figure 3 is a closeup of what the operator sees on the computer display. The grid overlaying the map detail is generated by the computer. The computer scans along each of these lines, called track lines, and processes the image data along the way. The processing is an algorithm that detects the intersections track lines and depth contours. What actually happens is that the computer follows the contour back to the previous track-line intersection and updates the depth for the newly detected point. When this operation is completed, it returns to processing the data along the track line until it encounters another intersection. If the computer is unable to follow the contour back to the previous intersection, the operator punches in the required depth information. The arrows shown on the display indicate that the intersections have been detected and processed, and the operator can thus verify that all the points were noted and add or delete information as needed.

The program for the Navy led to another program for processing map information that we call DIGIMAP. The technology developed for the Navy was extended to form a more general system for both digitizing or encoding map data and for postprocessing the information. Figure 4 shows the major hardware elements of the system: a flatbed image scanner (the input device), a minicomputer, and an interactive terminal. In the diagram, the blocks on the left form the digitizing system, and the blocks on the right form the postprocessing system.


Figure 2.--Calspan's SEASCAPE digitizing facility.

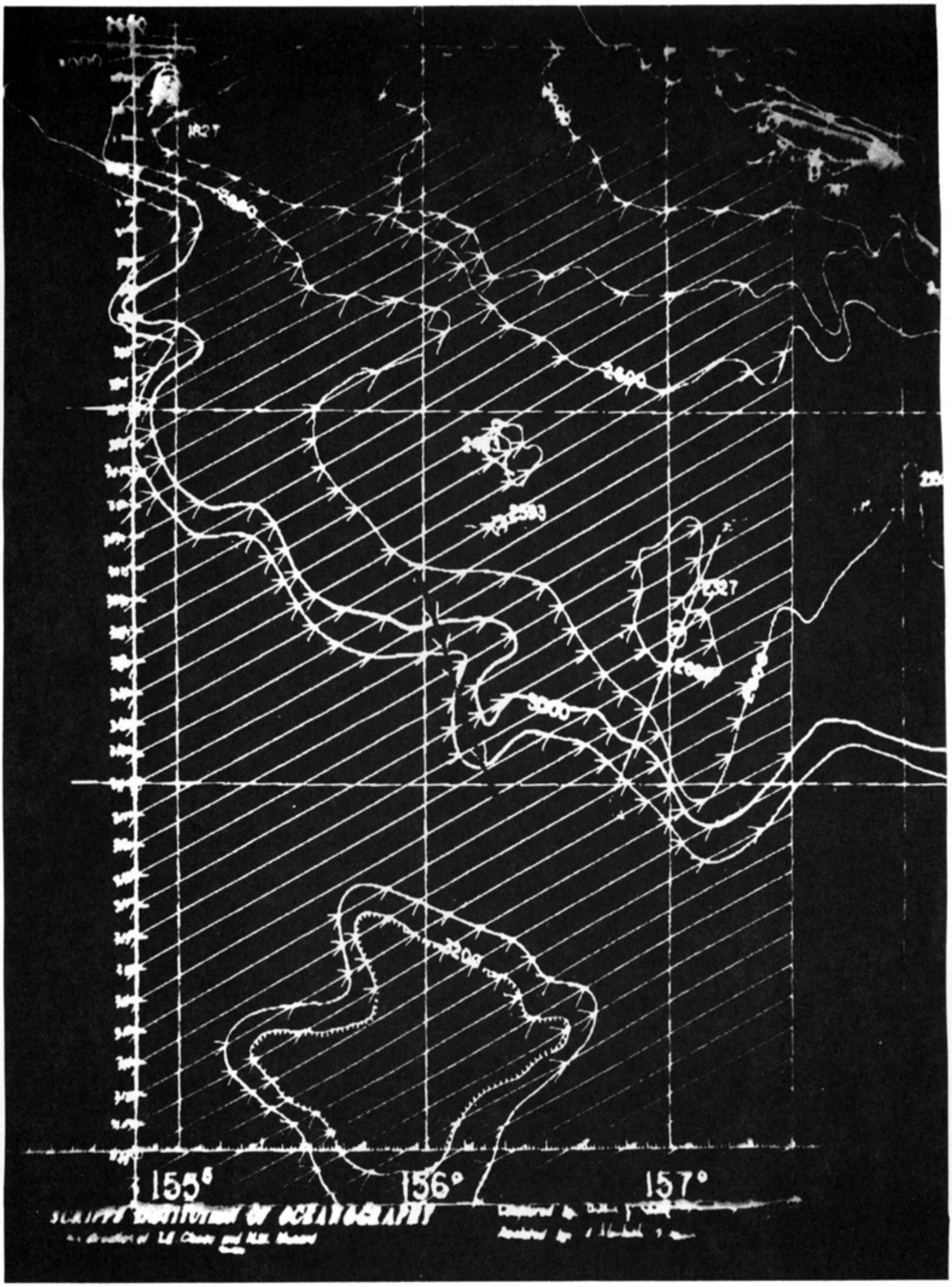



Figure 3.--SEASCAPE operator display.

HARDWARE CONFIGURATION FOR MAP DIGITIZING AND POST PROCESSING

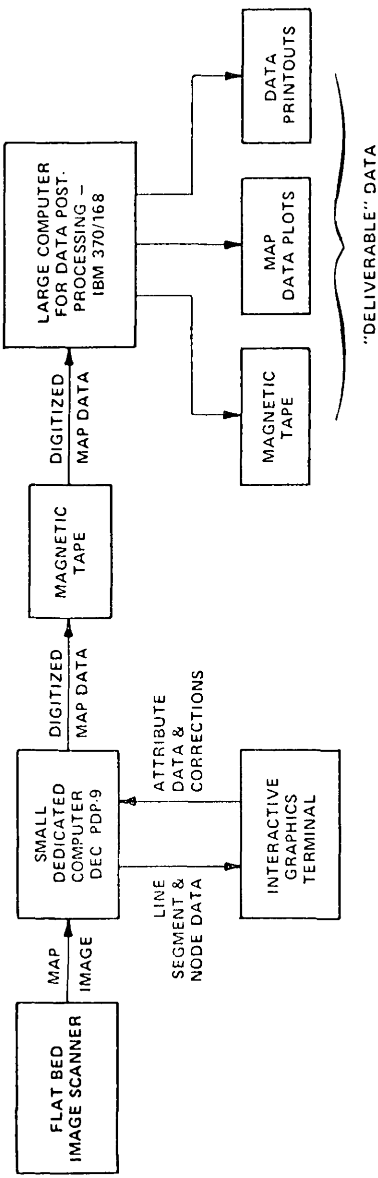



Figure 4

Figure 5 is another picture of our facility showing the flatbed image scanner in the forground (closeup in fig. 6). This device was developed in-house for scanning large documents. The key element of the scanner is a linear diode array which was discussed in an earlier presentation. The array has 512 elements and is mechanically driven across the table by x-y drive motors. Thus 512 points are scanned electronically. The scanner is a peripheral of the PDP-9 computer.

Figure 7 zooms in on the scanning head. The electronics are encased in the box; there is a simple optical system with a high-intensity tungsten halogen light. The room lights were turned off for this picture, but the scanner is normally operated with lights on.

I quite agree with Ray Boyle's earlier comment about it being difficult to separate digitizing from editing. Figure 8 illustrates the interactive editing operation with the DIGIMAP digitizing system. The scanning head is moved in a raster mode across the map being digitized, and the image data are transferred to the computer. In the computer, line-following image-processing algorithms locate, follow, and encode the lines on the map. Although the initial scan is done in a raster mode, the output is lineally encoded data; thus the system is a lineal or vector encoding digitizer. The map is processed in sections which correspond to half the size of the display. Note the bottom part of the display: the particular section of the map being processed is displayed, which is the raw image data as transferred to the computer. The digitized version of the same map section is displayed on the top of the split-screen. The operator compares the raw image data with the processed image data and then makes any needed corrections. There are a number of automatic editing functions, similar to the ones that Barry Moritz has described, which process the data before displaying. The key element in the minicomputer system is the disk that is used extensively to process the data.

Figure 9 is one example of a census tract map of Niagara Falls, N. Y. Our system has not been designed to process a map exactly like this one, but it is designed to process the unannotated version. We can process an annotated map like this, but it requires a lot of editing which runs up the cost of digitizing. The system is not designed to automatically edit out all of the alphanumeric symbols, although it does edit out some of them. Figure 10 shows the split-screen display of a section of the census tract map. This particular map was automatically divided into three sections for processing during the digitizing operation. Here, small boxes indicate nodes or intersections.

Figure 11 is another sample of a census tract map section which had been digitized and plotted with the tract code for each polygon. Here, only the polygons which are completely enclosed have been plotted. The plotting is done offline to the digitizing system; a CalComp-1136 plotter runs on our central IBM 370/168 computer facility. The maps are plotted to verify the digitized data. Figure 12 shows a tax map plotted from digital data.

In summary, Calspan Corp. has developed a semiautomatic digitizing or map-encoding system based on image processing technology. The system provides a means of encoding map data that is more accurate and less expensive than the basically manual systems which have been the major source of encoded data up to this time.

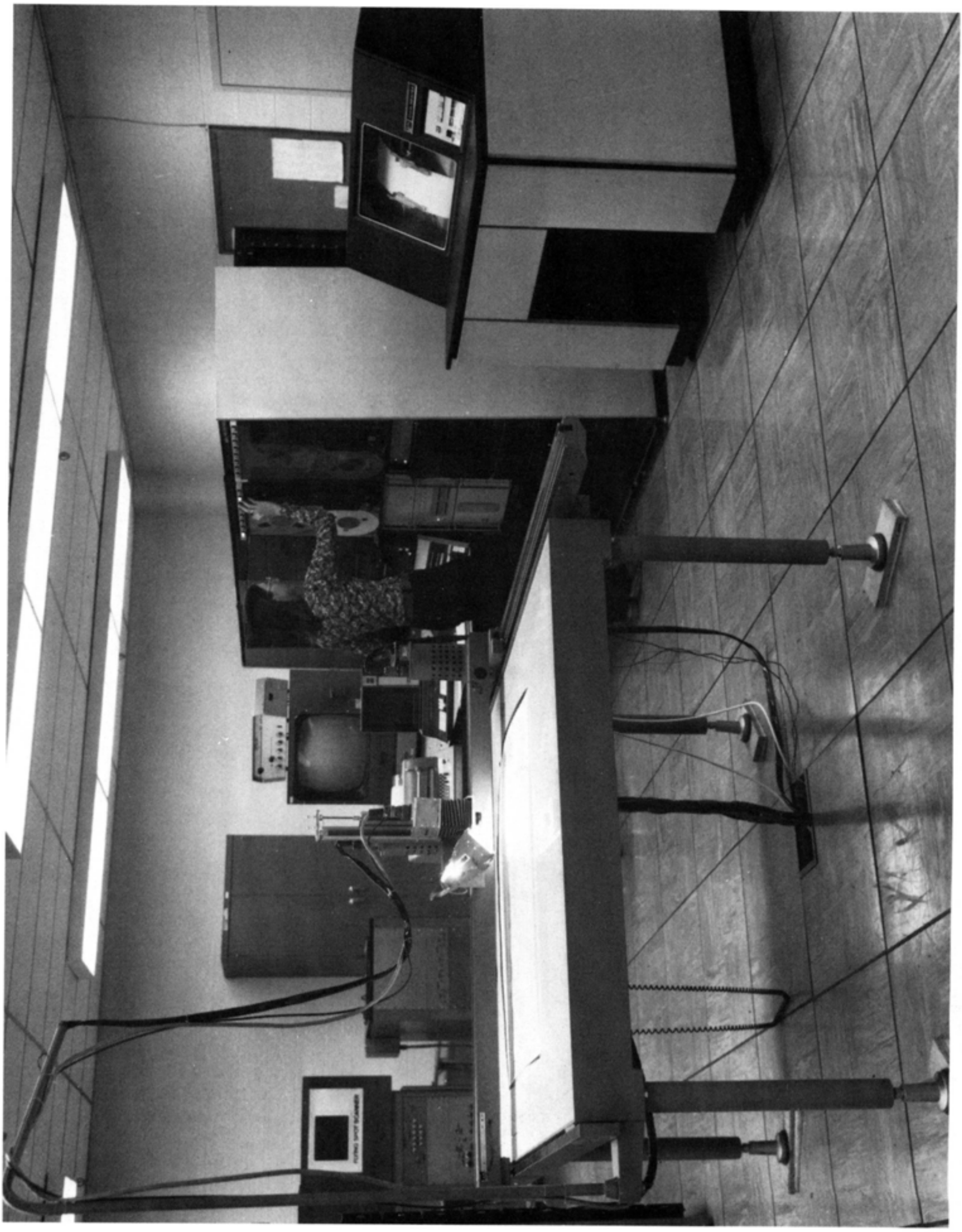


Figure 5.--Image processing laboratory.

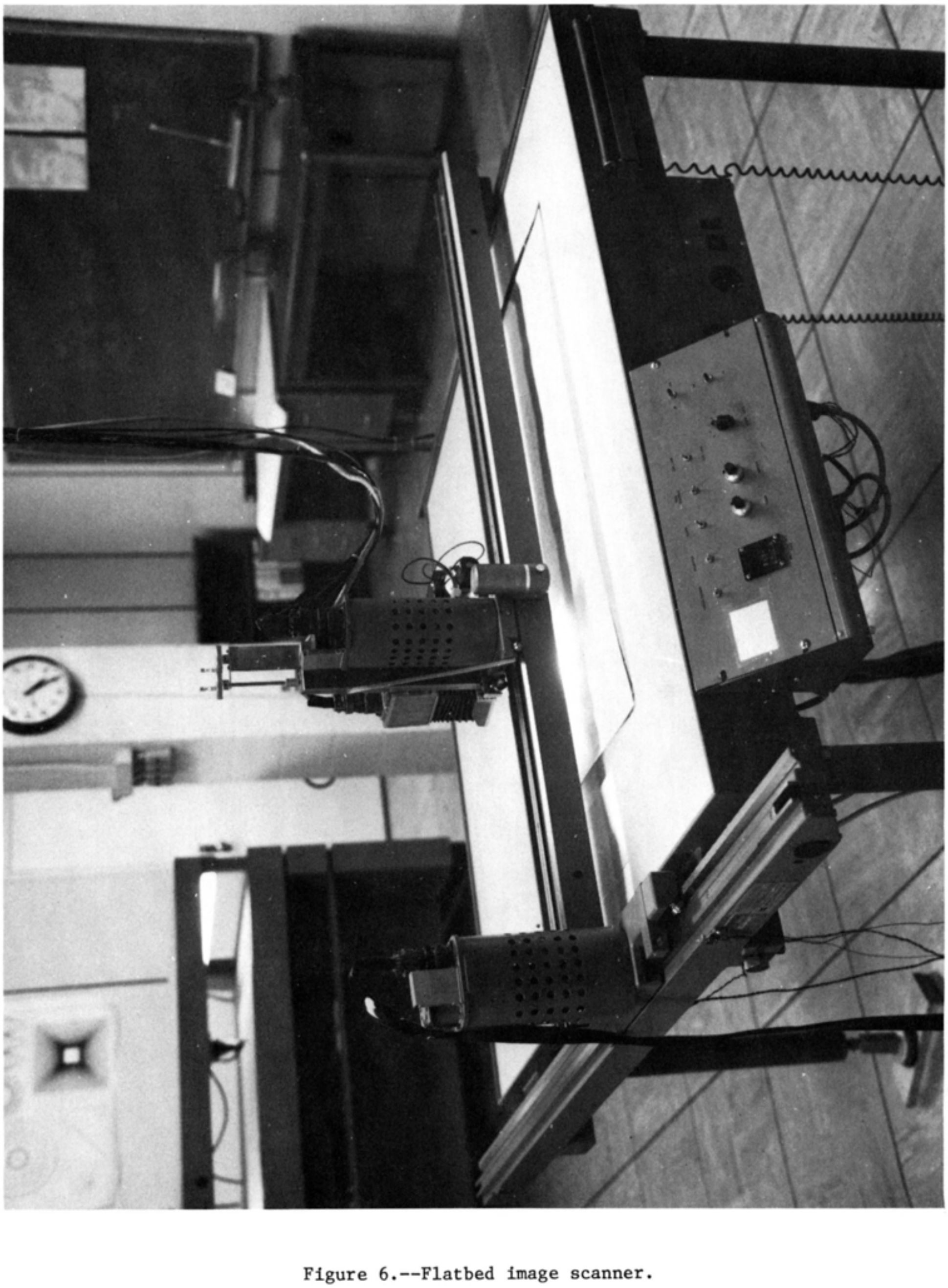


Figure 6.--Flatbed image scanner.

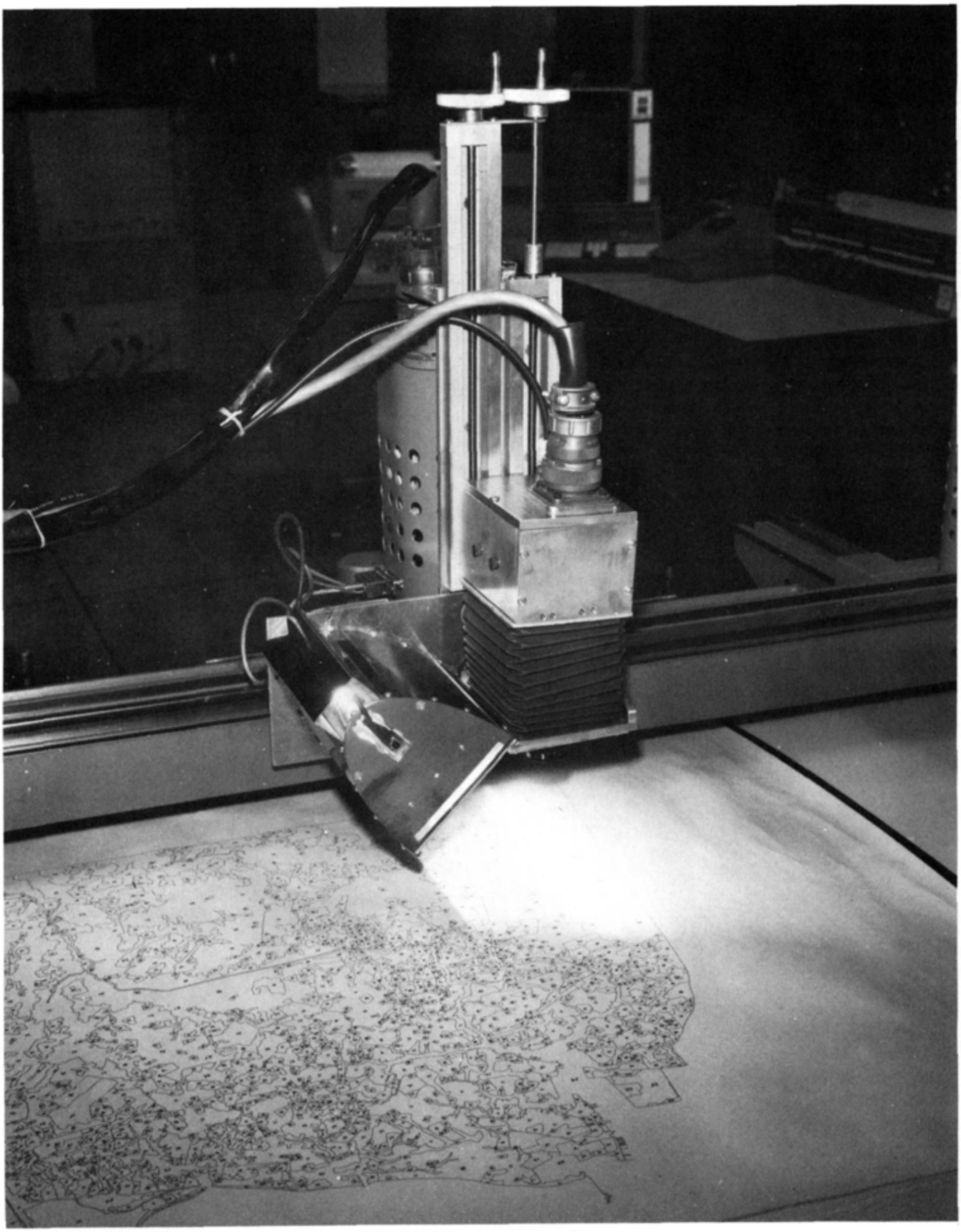


Figure 7.--Scanning-head assembly.

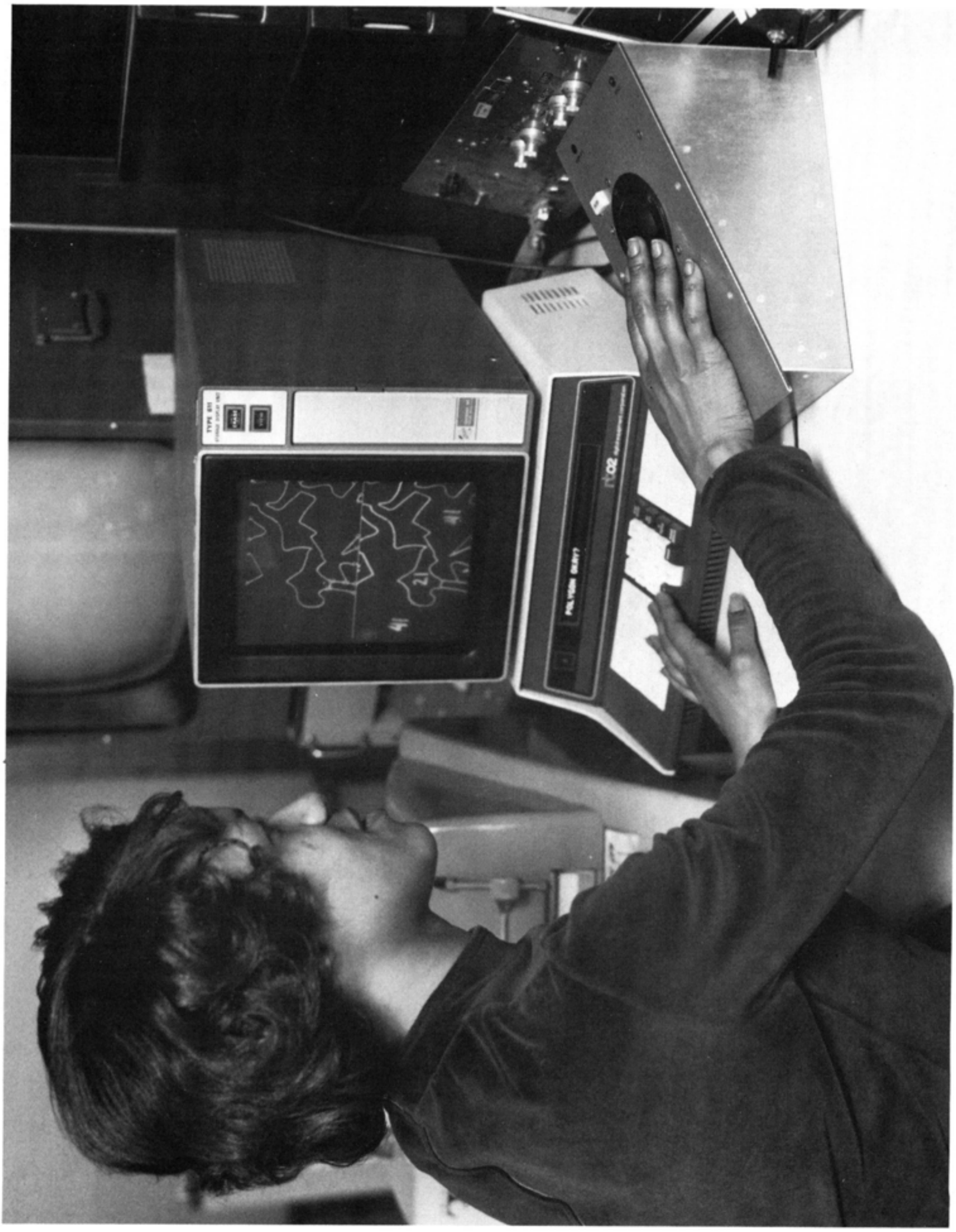


Figure 8.--DIGIMAP operator's split-screen display console.

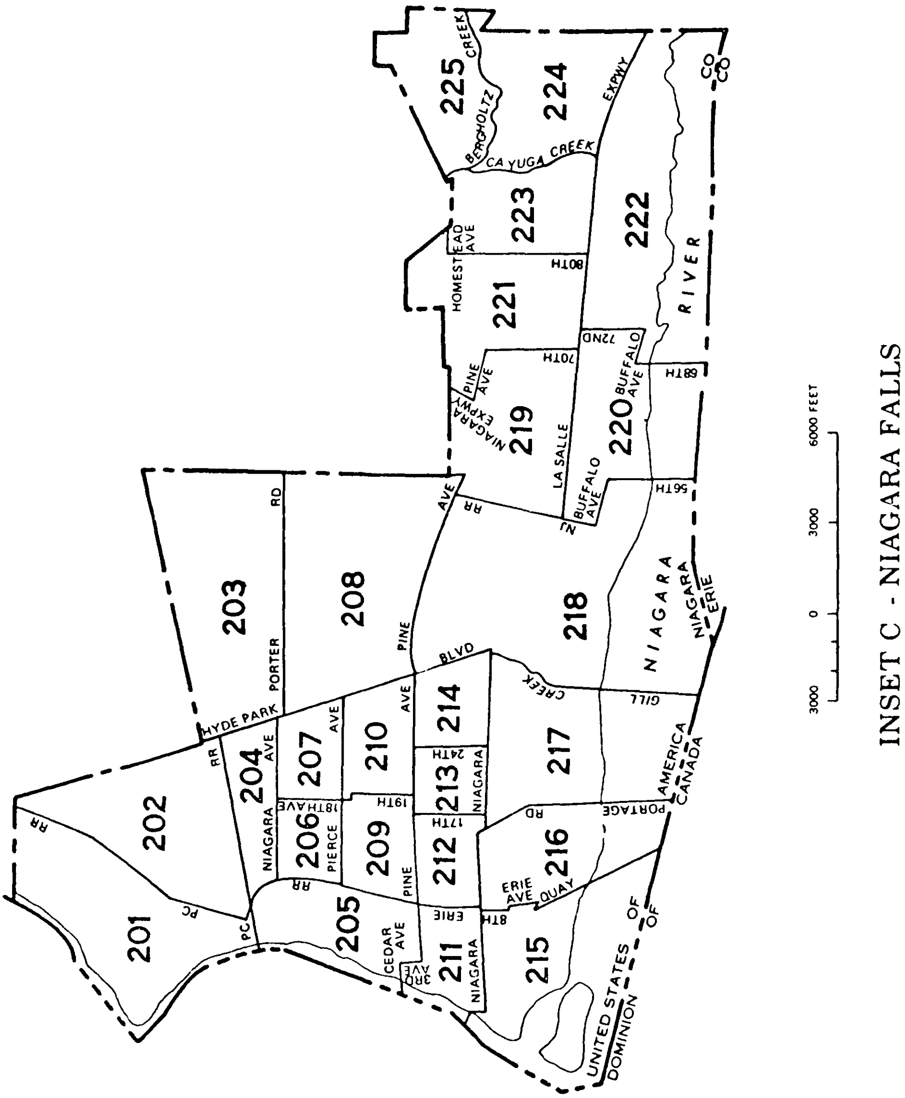



Figure 9.--Census tract map.

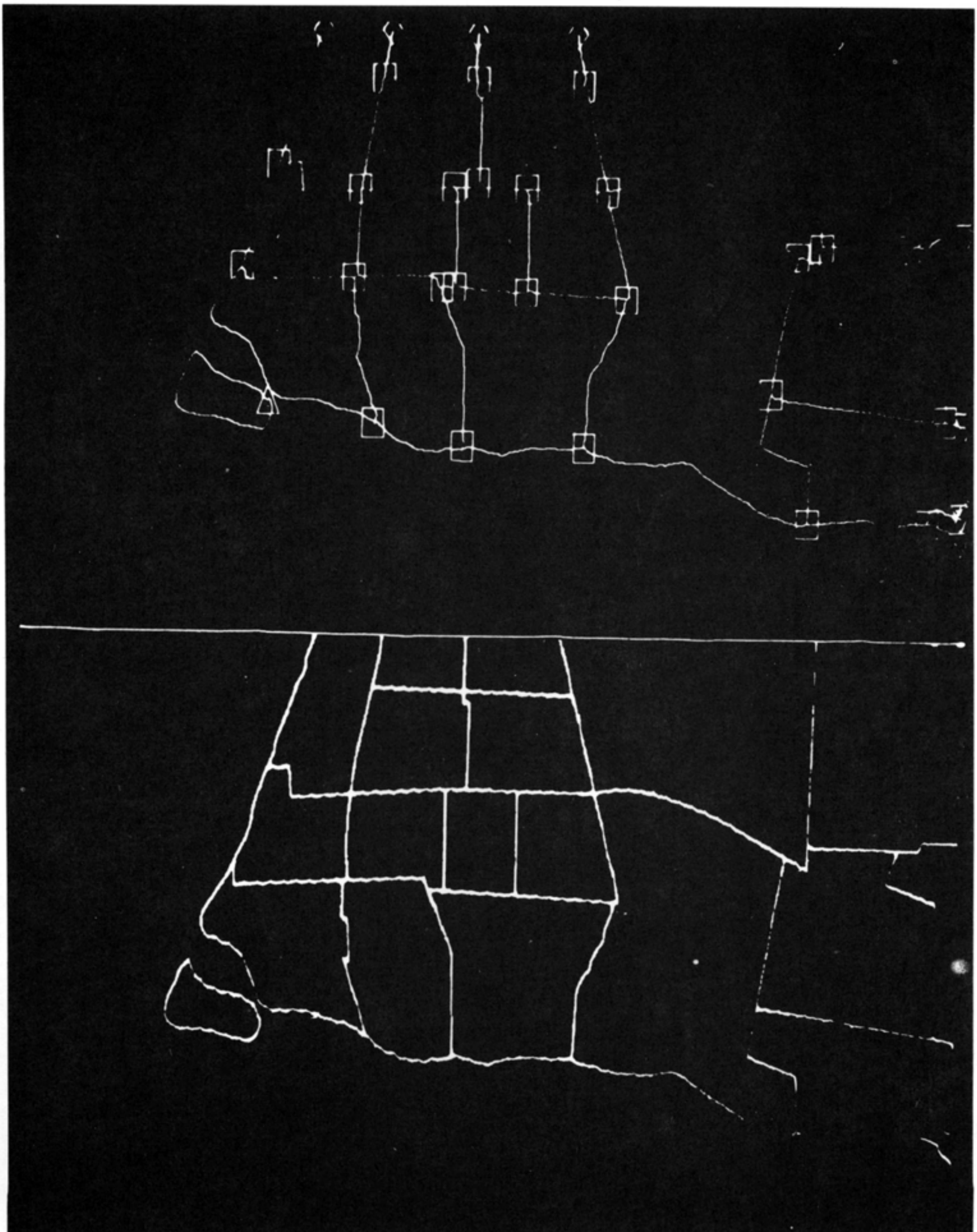


Figure 10.--Split-screen display of census map.

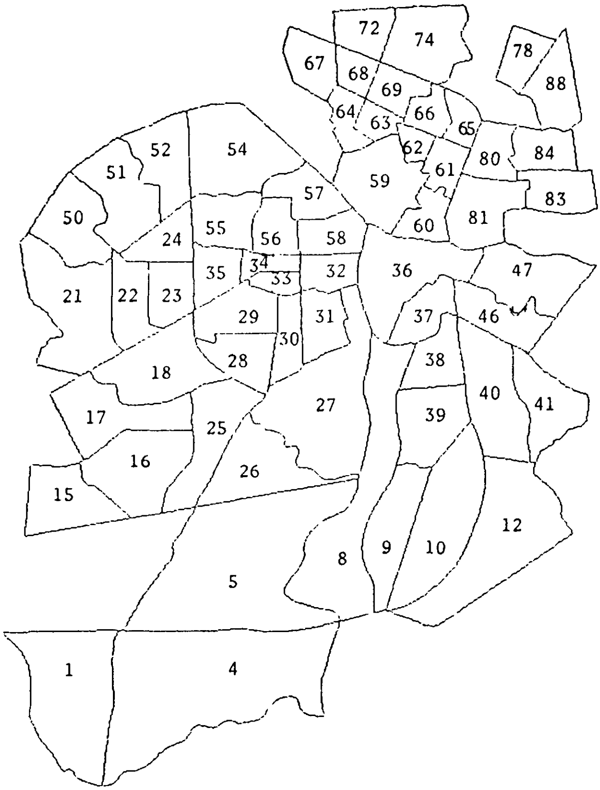



Figure 11.--Plot of digitized census map.

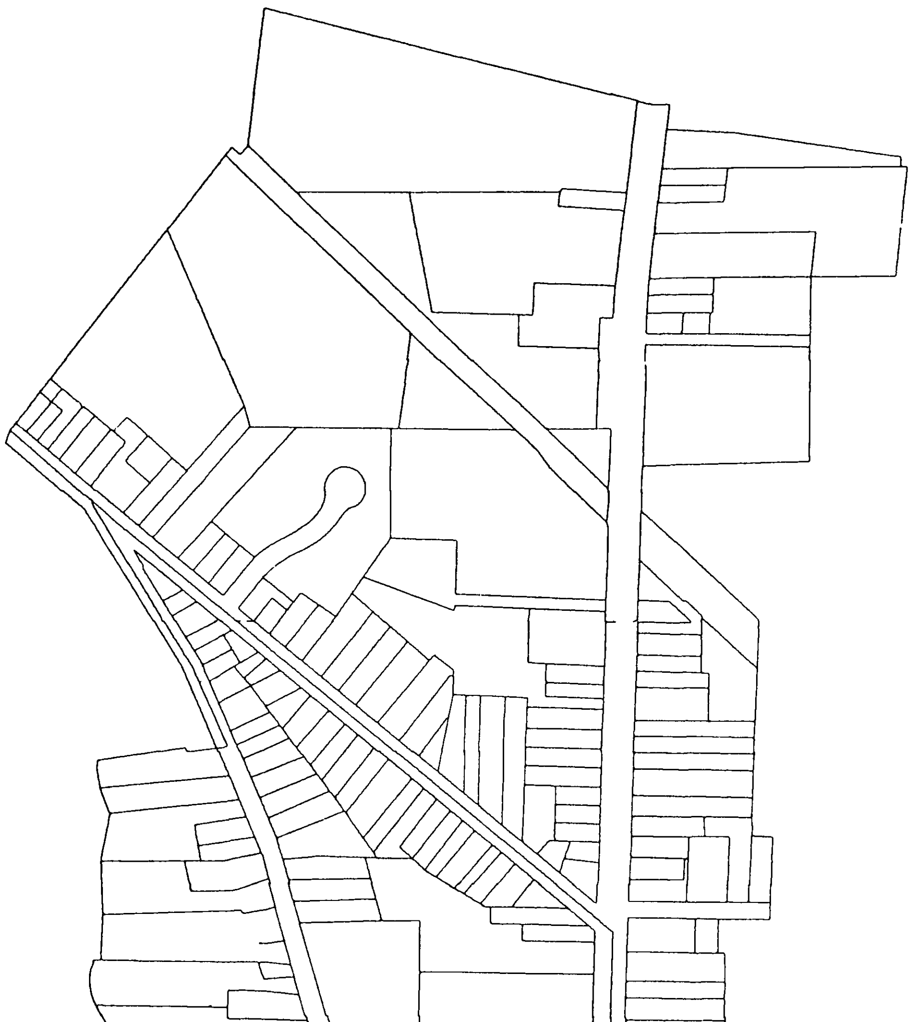


Figure 12.--Plot of tax map.

McDonough: As Olin Bockes pointed out, the question of data input has been around for a long time. The first Concord floating-arm graphic digitizer was built around 1960, and the system of 10 instruments that DMA Topographic Center has been using since then really generated the first bulk data file of graphic information--particularly terrain data--in the world. Surprisingly, one of the first large customers for that data was not a cartographic application but an electronic analysis application. The idea was that, in determining the interactions between radar sets and other electromagnetic devices, it is necessary to know something about the terrain where the devices lie. That was the first application, that I know of, for a large bulk file of digitized terrain information.

Those devices had a couple of elements that are extremely important in digitizing a very large amount of data. The purpose of the devices was to pick up terrain elevations from contour sheets. A lot of sheets were available; a lot of information was on them. One of the problems with digitizing contour sheets is that, when about 90-percent done, it is extremely difficult to review the digitizing and spot the last 10 percent of the contours. DMATC came up with a rather neat solution. They use the etched-zinc plate, of somewhat maligned reputation, and simply fill the lines with a colored water ink; as the digitizer is moved along the lines, the ink is scratched out. Thus, where the ink was scratched out, the line was digitized, and vice versa.

Lately, some other techniques have become available which have the same general characteristics; they rely on raster scanning the source material as opposed to linear detection. The raster scan approach has several interesting aspects. For a given-size sheet, raster scanning takes the same amount of time, regardless of the density of lines; a very dense contour sheet can be digitized in the same length of time as a sheet with one or two shorelines. Therefore, it is an extremely attractive technique to use when there is a large amount of information on a sheet. For certain applications, the raster form inherently contains a level of information separation or featurization when the source material is basically color-separated.

Raster scanning and raster plotting (the inverse process) permit the digitization and reconstruction of the graphics in a form that can be nondeteriorating, in contrast to the product of a series of photographic operations. Digital data allow line widths to be restandardized every time that you plot; you can then store the information in fundamental form as a graphic. This is particularly of interest to people who use perhaps one or two maps per application--utility maps, certain city planning maps, and similar materials--where the information is more readily stored in the graphic form, but a certain amount of editing or updating is desirable in digital form with an interactive editing system.

One difficulty with the raster technique is that featurization information is very crude. There is essentially no identification of individual linear features with a few exceptions, most notably the contour sheet. A couple of customers are successfully digitizing contour sheets entirely automatically--not for cartographic purposes primarily, but for terrain representation. Another customer has developed techniques for raster scanning well-prepared city planning charts, processing the data through a very large computer system, and producing lists of blocks, block sizes, street locations, associations of street-number ranges with certain block identification, and census tracts.

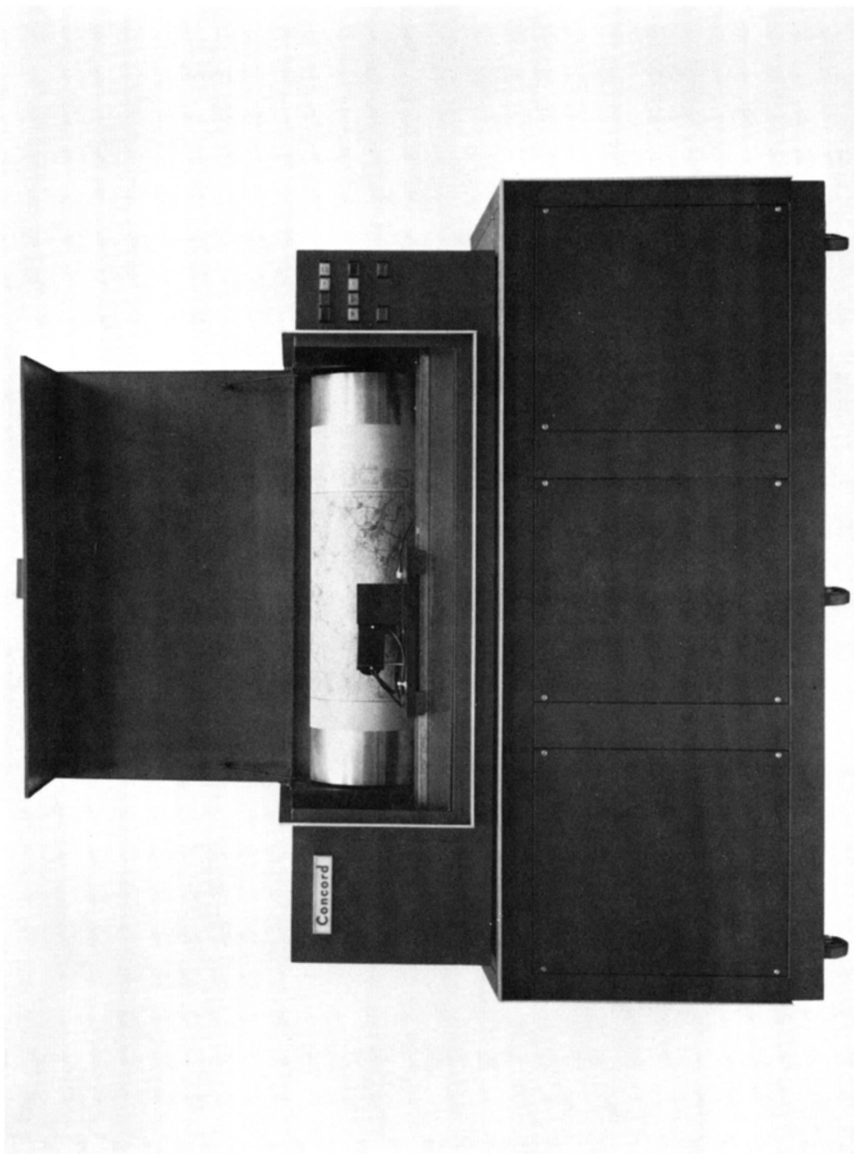
To go further requires some conversion of the raster data to linear format. The simplest way to do that is to turn a line-tracking algorithm loose on the raster data, let it track along the line until it comes to an intersection, and call each line segment between intersections a separate microfeature. Then a person will edit or connect the microfeatures representing one macrofeature. Each river, each road, and each contour on a composite sheet would be separated into little pieces which someone has to hook back together again.

In the last couple of years, a combined system was developed for RADC in which raster data are processed in connection with a manual digitizer. The manual digitizer works with a second copy of the source document. By rapidly digitizing approximately over a selected feature, the operator triggers the system to search the raster data for the specific location of lines most closely fitting the rough track data. The particular device now at RADC uses an online raster system in which a second copy of the map is on a scanner and as the operator makes a rough track, the scanner actually does the detailed digitization. The same sort of thing can be done by accessing data that were previously in a raster file.

Raster data appear to be much more bulky than linear featurized data. On the other hand, for materials such as dense contour sheets, the additional bulk is not spectacular if reasonable data compression techniques are used on the raster plotter. For various reasons many of the practical data base file systems that are based on linear data use a very high density of data along the linear feature. One of the reasons is to provide an easy means of aiming at a feature and finding a point. As a result, a reasonably sized raster file requires two or three reels of raster tape, as does roughly the same amount of information in one of the more densely recorded types of lineal format.

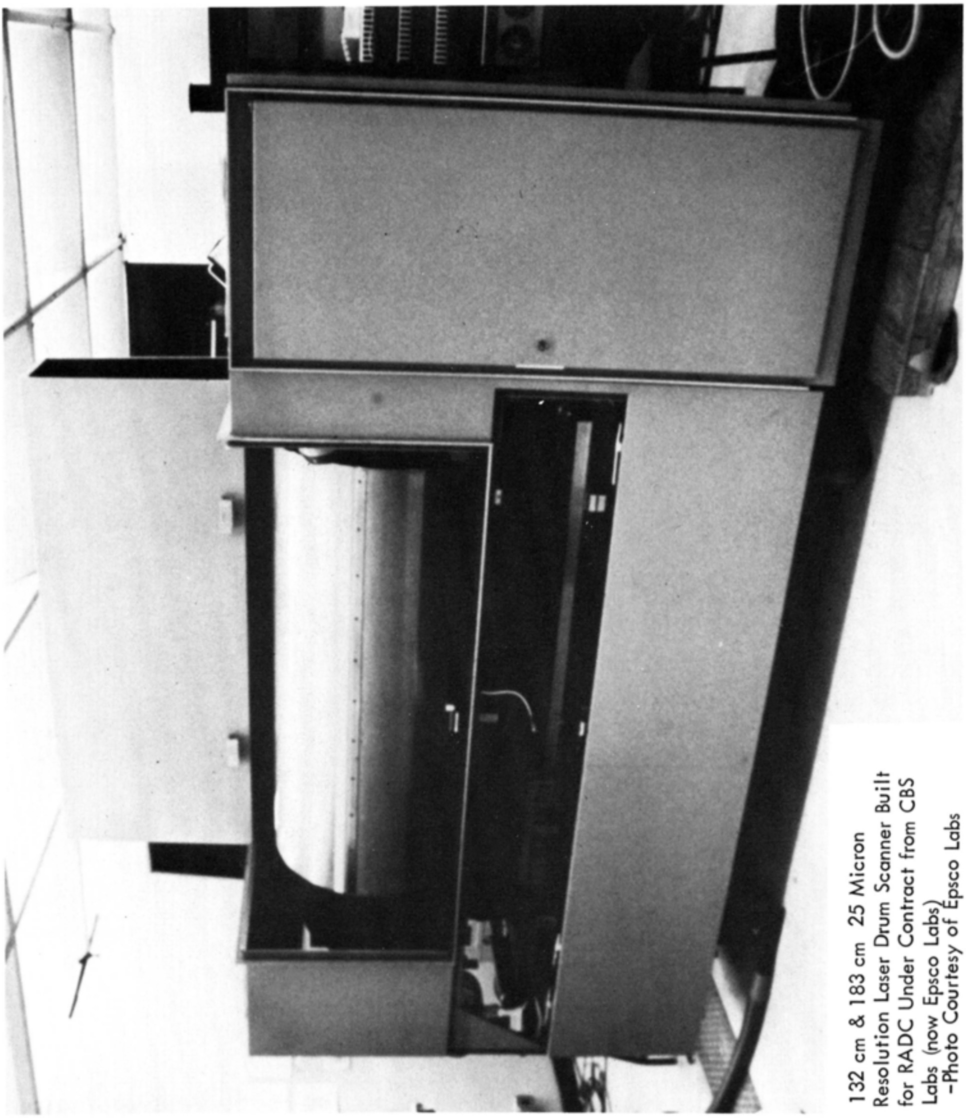
It is also possible to edit raster data directly in a raster format. With an interactive editing system it is possible to build up a small section of corrected data by any of the techniques--linear, raster, or whatever--and simply cut or "window" that data into the basic file. RADC has developed techniques for cutting in edited data and making the lines fit.

Concord Control has built a couple of raster scanning systems (fig. 1) that are being used in Europe for generating terrain elevation information. Presently Concord is working as a subcontractor for CBS Laboratories in the development of two very large, very high-speed raster scanner plotters for RADC (to be installed at DMATC and DMAAC). The systems measure about 52 by 72 in and are capable of producing either a scan file or plot in 30 min on a full-size sheet of film. It is a drum type scanner (fig. 2); and the scan carriage scans six tracks simultaneously around the drum, advances six lines, scans the next six tracks, and so on. Basic resolution is 25 μm, or 1,000 lines/in, for both axes. Concord also has developed, again mostly for RADC, a series of interactive graphic systems which combine linear plotting and linear digitizing capability.




Concord 90 cm x 81.92 cm Drum Raster
Digitizer - Mark 3

Figure 1



132 cm & 183 cm 25 Micron Resolution Laser Drum Scanner Built for RADC Under Contract from CBS Labs (now Epsco Labs)
–Photo Courtesy of Epsco Labs

Figure 2

The old days of the operator laboriously following lines with a cursor or pushing a phonograph needle along grooves in an etched-zinc plate are over; digitization of a map file probably requires a little more human effort than went into the generation of the file on the first place. Now there are very rapid techniques for getting data into a digital data base by means of raster scanning. Some very sophisticated and reasonably efficient techniques exist that will convert raster data into editable form, by working in subsections of raster data or by derasterizing the data into linear format. One can take a composite raster file and extract specific isolated features desired for compiling a new product.

Peucker (Simon Fraser Univ.): When you raster scan an image which has a lot of dirty spots--ink and so on--you catch that, and you have to use quite an elaborate system and be reasonably efficient to get it out. With automated line following, you have a similar problem with this cutting across or not finding links. Therefore I really would like to see a description of a think-automated digitization process where difficult corners and difficult spots are marked beforehand by an operator and eliminated during the process of scanning rather than in an empty process.

McDonough: My own approach to the question of human interaction is that you should do as little preprocessing for the machine as possible. I think it is a difficult and time-consuming job to try to outguess a machine. Being somewhat of a software-man myself, I have spent a lot of time trying to outguess machines. The opposite approach is to use a process in which you can take advantage of the characteristics of the data and just ignore the dirt. The isolated dirt becomes a small feature whose total geographic dimensions are too small to accept. Similar criteria are used to distinguish isolated alphanumerics or other symbology from the linework.

On the contour sheet the lines are alledgedly all standardized in width. The system can select out of a glob of ink a standard-width line that either runs along the edge of the glob or through the middle of it; likewise contours can be peeled off one at a time from a coalesced area. These things have all been done. The difficulty is when a composite situation arises, like alphanumerics running into or across linework. In many cases, you don't have to clean all of that stuff out of the file unless you are looking for a total file of clean data. Such things as locations of telephone poles and management information can be extracted without cleaning the file.

The city planning system was a large IBM 750; the DMA system uses 1108 processing with a complex of minicomputers. Several hours/sheet are required, but there are only 35 sheets, so it is not a ridiculous application.

Bockes: I can't resist the suggestion that part of the problem raised by Peucker about ink spots and such may be caused by using second-generation information which is already in two-dimensional map form. We should not forget that terrain is three-dimensional information that might be better collected before you get to the map stage. This third dimension is an important factor; we may have damaged our digitizing by putting it first in a two dimensional map form and then trying to get it back into three-dimensional domain.

Wohlmut: Although i/o Metrics is concerned with all aspects of information retrieval from film, I will discuss only the method by which we digitize film-based data with the system that I outlined quickly in a previous session. As a service organization, i/o Metrics caters to a number of users with different kinds of data. A good part of the digitizing does not involve a direct correspondence between input film data and x-y coordinate output. For example, in high-energy physics we deal with geometric coordinates on a piece of film and desire output as kinematic variables of energy and momentum. Another project involved scanning 20 ft of coiled wire and producing a histogram of the variation in thickness.

We have attempted to set up a system that produces the final digital output in as easy and general a fashion as possible. In some applications the approach is raster scanning or a modified raster scanning with strings of density information. However, automatic line-following is used in most applications because the total amount of processing and editing time is minimized. We use a laser scanning device which has x-y random position capability and can sample or generate position, direction, density, and line-width information under computer control. Currently, we have three devices: one is in the final stage of development (should be available in 6 months) and will be able to scan a 5-ft-square area: the other two will scan a 105-mm-square area with an absolute accuracy of 2 µm. The systems enable sampling the x-y position of a point, line, or other physical attribute at any time as well as instructing the probe to move to certain x-y coordinates.

Besides knowing x-y coordinates at all times, two other variables are sampled: the percent transmission of light through the information base and, for automatic line following, the pulse width of the object of interest. The system operates with FORTRAN programing which is highly modular. At any time, if one can either precisely or statistically define a given object of interest in terms of the above parameters, the machine will very satisfactorily decide whether to try to automatically follow a line one way or another, whether to ignore a piece of information, whether to accept it and continue, or whether to seek operator assistance.

The system (fig. 1) basically consists of three elements--the film-plane digitizing stage, an interface to a computer (currently a Unichannel PDP15), and a control console which permits an operator to monitor the operation and to interact with the device and/or the computer at will. The latter feature enables on-line editing and correction and correction of unprogramed conditions.

The characteristics of the scanner itself include those of the deflection system that I described very quickly in an earlier session. Figure 2 shows the optical paths of the system. The film plane is set 1 m from the deflection system, largely for our own convenience since most of the formats that we have dealt with were under 105-mm on a side. The deflection mirrors move over the film plane under computer control, and the probe beam, a 1.5-mw helium neon laser, is focused down on the film. The beam passes through some beam-collection optics, through the film, and into a photomultiplier (PM) tube which is clocked in with the other information that I described previously, so that we know at any given time where we are and what the signal looks like.

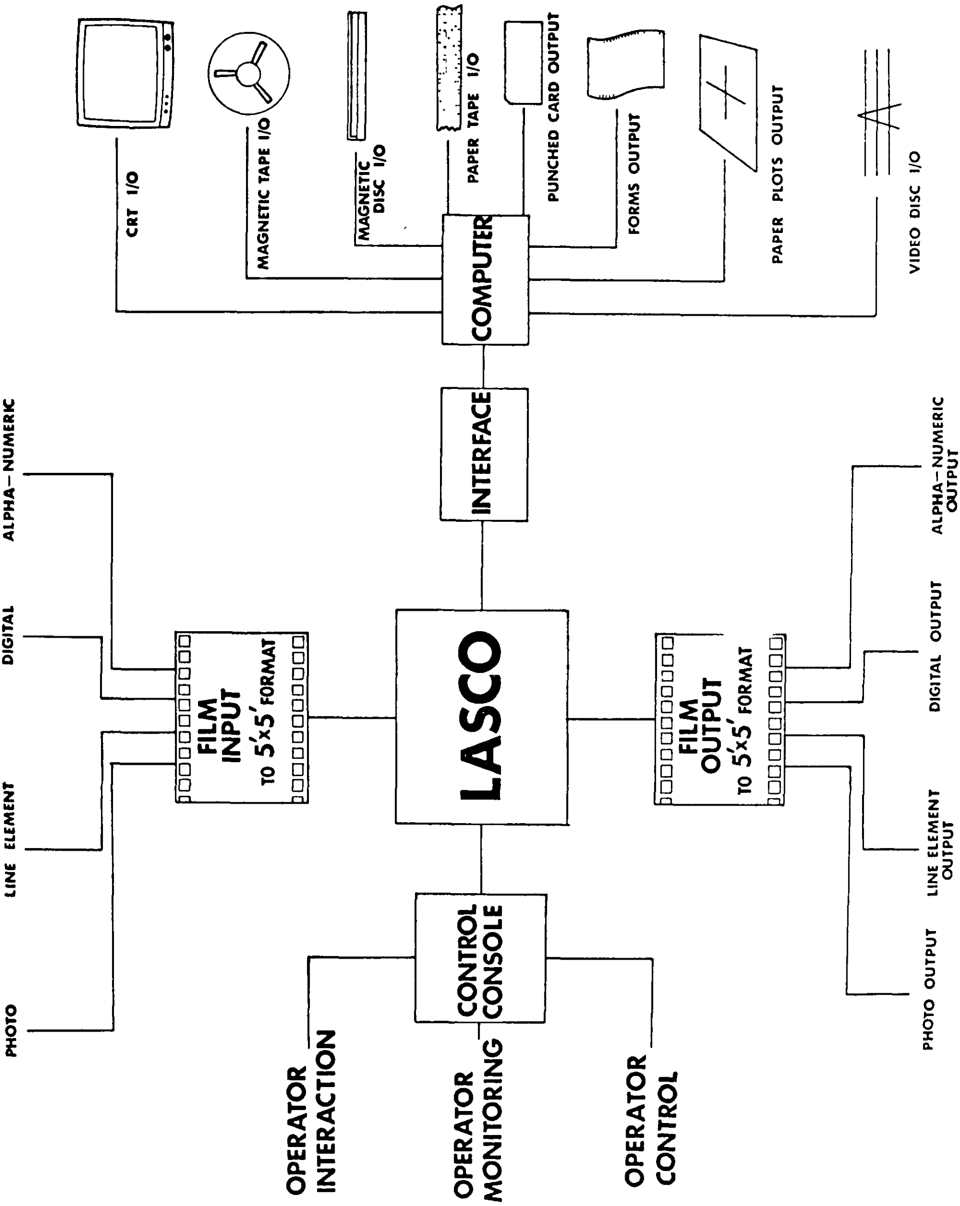

CRT I/O
MAGNETIC TAPE I/O
MAGNETIC DISC I/O
PAPER TAPE I/O
PUNCHED CARD OUTPUT
FORMS OUTPUT
PAPER PLOTS OUTPUT
VIDEO DISC I/O
COMPUTER
INTERFACE
LASCO
CONTROL CONSOLE
FILM INPUT TO 5'x5' FORMAT
FILM OUTPUT TO 5'x5' FORMAT
ALPHA-NUMERIC
DIGITAL
LINE ELEMENT
PHOTO
ALPHA-NUMERIC OUTPUT
DIGITAL OUTPUT
LINE ELEMENT OUTPUT
PHOTO OUTPUT
OPERATOR INTERACTION
OPERATOR MONITORING
OPERATOR CONTROL

Figure 1

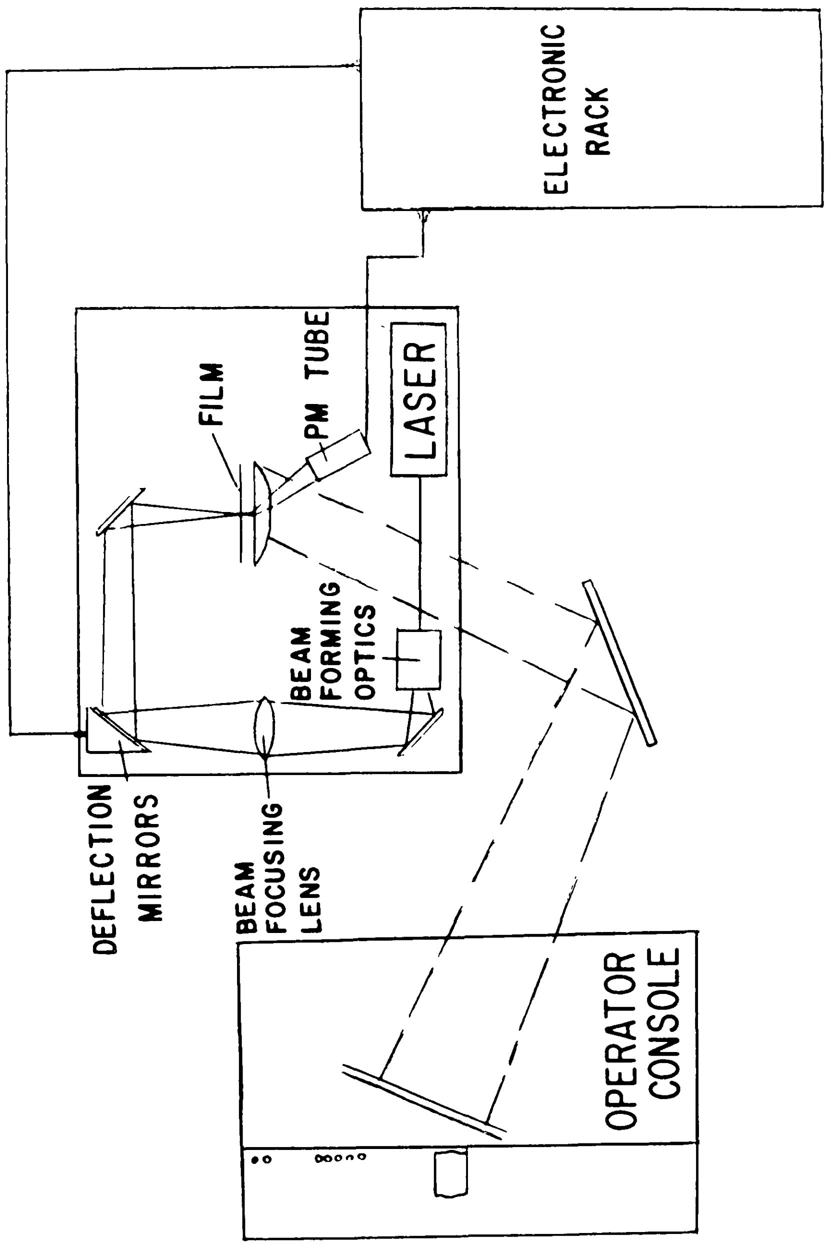

ELECTRONIC RACK
LASER
PM TUBE
FILM
BEAM FORMING OPTICS
DEFLECTION MIRRORS
BEAM FOCUSING LENS
OPERATOR CONSOLE

Figure 2

To assist the operator in monitoring, a reverse beam of mercury arc light goes back through the system and produces a large screen blowup of what is being digitized. At the same time, a closed-circuit TV monitor gives a picture of the immediate area around the probe. The console also has a Tektronix 611 display which graphically shows the actual coordinates digitized. There is a teletype for commanding special functions. In addition, there is an oscilloscope which shows the signal quality as the scanner samples the film.

Raster scanning is performed in a standard fashion. A 10-μm spot can be produced with a 1-m throw. The spot can be moved randomly or sequentially in x and y.

For automatic line-following, a 10-μm spot rotates in an orbit with an arbitrary radius up to about 2.5 mm. The radius is arbitrary to the extent that it can be programed or it can be set manually; however, there are particular radii that are known to work best for certain applications. The computer knows the precise center of the orbit to an absolute accuracy of 2 μm. The radius is determined fairly precisely by a calibration technique we use; for a 1-mm radius, the accuracy is again about 2 μm. The angular position of the probe is known at any given time to an accuracy of 1 part in 4096--a somewhat arbitrary limitation because accuracy is only restricted by the size of the counter and the rate that the image is spinning. For most line-following applications, the point on the circle spins at the rate of 150 r/sec, which is a little faster than the software will handle most of the decisionmaking. However, one is able to automatically line follow and digitize on any arbitrary curve between 50 and 100 points at a spacing anywhere from 1 μm to 2 mm. The choice of coordinate point spacing depends on the output desired and partially on the complexity of the curves. For rapidly varying curves, the sampling rate is high in order to preserve the integrity of the data and to facilitate searching for the next data point under computer control. Digitizing is typically carried out at 5- to 10-mil increments at about 100 points/sec.

Part of the programing for line following involves knowing the x-y coordinate location and knowing something about the history of the line, or track, that we are digitizing. As the probe crosses the track, the density of the track is measured by the transmission of light, and the track width is measured by the number of angular counts for which the measured density exists during a sweep of the probe. The PM tube displays a straight line when no data are present; when the probe crosses a track, the PM tube displays a dip or "bucket" of a width that is a function of the track width and of a depth that is a function of the density. The probe steps along the track while the computer records and predicts where to look next. The computer can be selective in sampling a particular angle; in other words, you have to sample density all the way around the probe orbit. As a history is built up the opening angle is selectively narrowed down to reduce any confusing effects of dirt on the sides or of tracks closely parallel to the track of interest.

The rotating point can be extended into a line segment. This was typically done early in the development of the digitizer for following bubble-chamber films, which really don't contain very well-defined tracks but consist of series of bubbles with sizable gaps

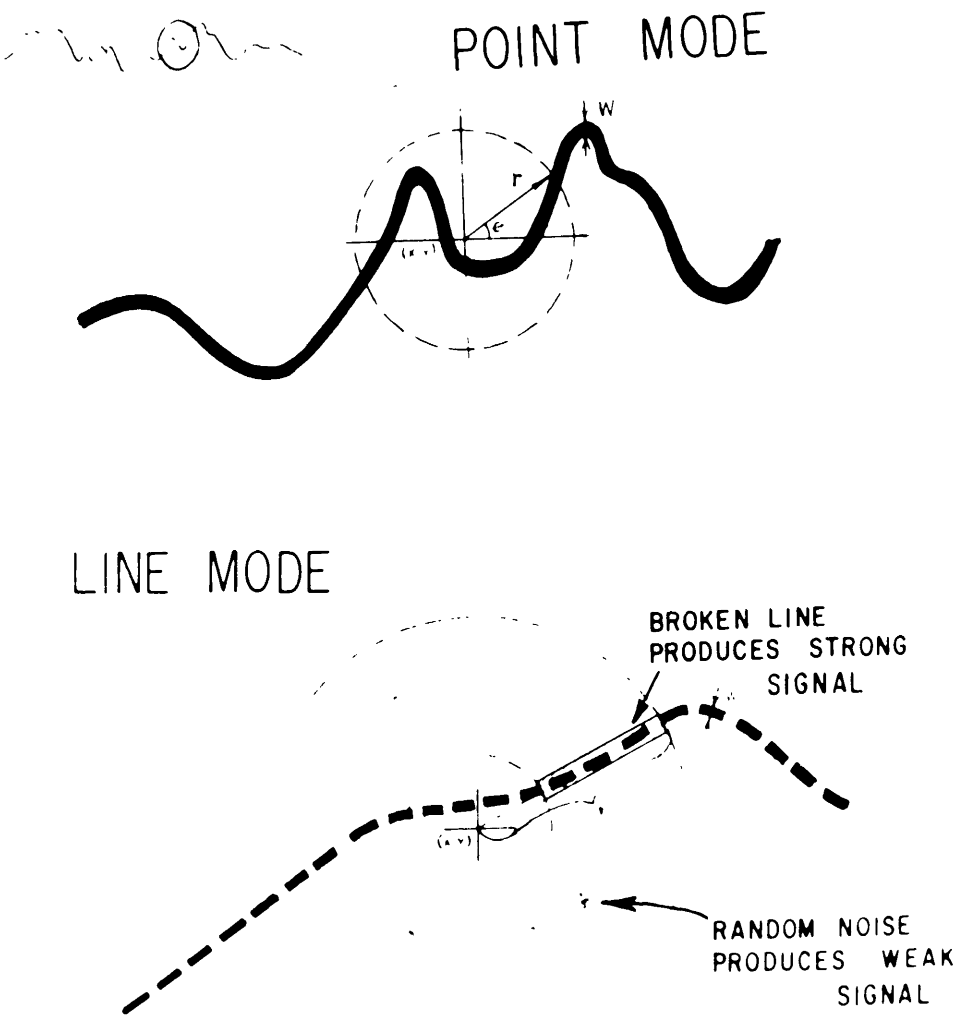

POINT MODE
W
r
LINE MODE
BROKEN LINE
PRODUCES STRONG
SIGNAL
RANDOM NOISE
PRODUCES WEAK
SIGNAL

Figure 3

on very low-quality film. Sampling (fig. 3) by averaging over an area larger than the 10-μm spot is not a very effective technique when you encounter tracks that rapidly change direction, but it is a most useful technique for "well-behaved" lines which have large gaps or irregular line width. In addition, the step size can be changed typically to handle drastic variations of the direction of the track. Effectively one can obtain only those coordinates of a line which will define the line variation with a predetermined accuracy.

Figure 4 shows a plot produced by the same probe used to measure the data by exposing the film under computer control rather than sampling. A standard land-use sheet is cut into 105-by 105-mm sections, digitized separately by using fiducial marks as common reference points, recombined, edited and perhaps digitized in selected areas, and then plotted.

The procedure for digitizing the land-use data shown in figure 3 was as follows: We were provided with a digital tape of a land-use data--label information on each of the polygons and coordinates of a point within each polygon. As the tape is read, the probe jumps automatically to the given center point in the polygon and then hunts in one direction for the start of a line element. The operator can override the procedure if the probe is not hunting efficiently and can position the probe manually. The probe automatically follows the track in either direction. When an intersection is reached, the probe "tells" the computer that a line segment was completed and/or a new line segment is starting, and then it proceeds to close the polygon. Thus the digitized data are coordinates of closed polygons with line segments which are coded appropriately; the output can be in any format that is compatible with the user's needs. This is all done with minimal editing. The plot in figure 4 represents 150,000 points at 10-mil spacing, which corresponds to 300,000 18-bit words. In this case, some areas were redigitized to see how well the data compared with the original measurements; after reconstruction the variance amounted to 0.001 in over a 5- by 5-ft area.

Figure 5 shows one corner of a map, the most extreme corner from the origin of the system. The darkest features represent the overlap between two adjacent segments. The dark lines are the remeasurements on top of the original measurements. The result is that we can combine data and achieve better than 1-mil accuracy over the entire area without manipulating the raw data other than translation and rotation.

In summary, we feel that we have demonstrated a viable technique for producing a digital data base which is accurate, efficient, and most effective and which is currently in operation.

Chrisman: I want the chance to question this in depth, but time just doesn't allow it.

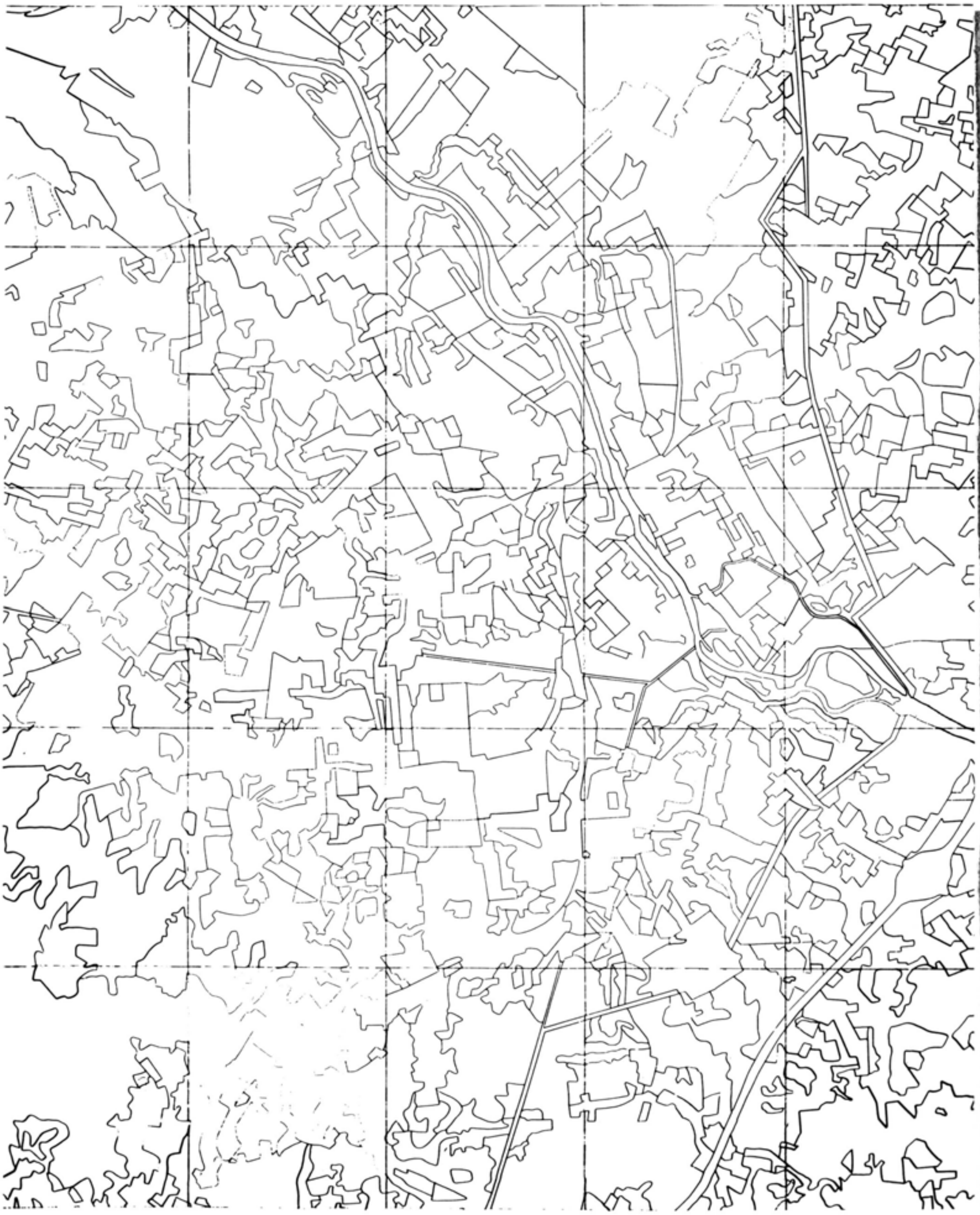


Figure 4

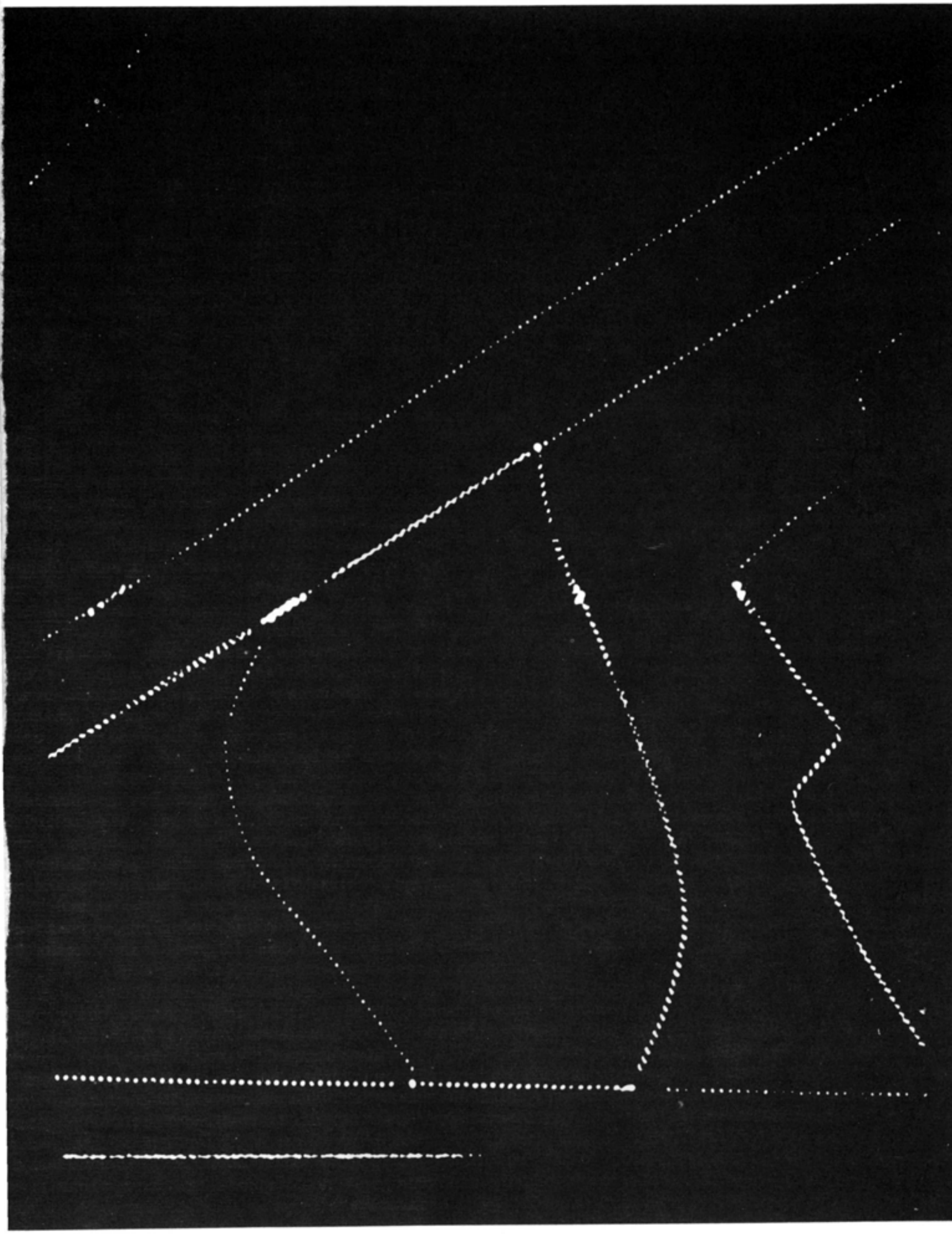


Figure 5

Stiefel (Analytical Systems Engineering): It seems that one of the threads running through the entire conference so far is that we have effectively buried manual digitization. Is it possible to digitize to National Map Accuracy Standards using manual digitization techniques, or are we stuck with automatic scanning which obviously means a larger investment? A lot of people here have a great deal invested in manual equipment. If it is true that manual digitization is not practical, where can we apply manual systems, and where must we go to automatic scanning?

Wohlmut: The land-use plot that I showed you, representing 150,000 points, was provided at a total cost of $450 for error-free output.

Stiefel: I have no way of determining your accounting method.

Wohlmut: That is all that it would cost you for an equivalent map. There are other things that would go into it. How would you use an automatic device completely? There is always some major operator intervention required; the more manual intervention, the higher the cost. I doubt that it is ever possible to have a completely automatic system. There will always be things that will require an operator's assistance.

Stiefel: Yes, that is one side of the question, but how about the manual-digitization people?

Chrisman: I don't see any point in a person recognizing the feature and sending the device to it. To digitize the DIME file by this system, the operator would be spending just as much time as he would with a manual system because he would have to identify each street segment, each address range, and the left and right polygon, which is precisely what he would have to do in the manual system. He would have to have previously entered the address range, the polygon centroids, and the polygon outlines.

You have a wonderous piece of hardware. I don't see how this hardware identifies geographical objects. I have seen what you have done for Lawrence Berkley Labs--a line scanner that has a real problem at line intersections and requires a lot of hand intervention. I saw that project; 70 percent of the effort was getting rid of the node errors and 30 percent was letting the machine digitize the rest.

Wohlmut: I can say categorically that such problems do not exist. You are talking about a pilot project that was conducted overtly, and the early stages involved quite a lot of development work. At this time, the machine recognizes corners and places in the corners, well within the accuracy requirements of the contracts.

# ICA Commission III Panel

Gordon E. Stine, Presiding
Chairman, ICA Commission III

Joseph Diello
Rome Air Development Center

Vincent J. Nardozza
Rome Air Development Center

Hans-Jorg Gottschalk
Institute for Applied Geodesy
Federal Republic of Germany

Christian Hoinkes
Swiss Federal Institute of Technology

Stine: The International Cartographic Association (ICA) was conceived at a conference on applied cartography in Stokholm in 1956. The proposal that international cartographic cooperation be investigated was re-emphasized by delegates to the Second International Cartographic Conference sponsored by Rand-McNally & Co. in 1958. The ICA statutes were formally adopted at the first general assembly in Paris in 1961.

The aim of the association is to advance the study of cartographic problems. In particular, the ICA is concerned with source material, compilation, graphic design, scribing, and reproduction of maps and associated forms of graphic representation. The coordination of cartographic research involves cooperation between different nations and different scientific groups: exchanging ideas of cartographic knowledge, organizing international technical conferences and exhibitions, participating in similar meetings, and establishing special commissions to work on specific problems. The ICA is affiliated with the International Geographical Union, and they hold joint assemblies every 4 yr. The ICA also holds technical conferences biennially.

Each nation can only be represented by a member of one organization, preferably a national cartographic society or committee. Individuals can not be admitted as members. The Cartography Division of the American Congress on Surveying and Mapping was designated the official organization to represent U.S. cartographic activities. The Fifth General Assembly of the Eighth Cartographic Conference of ICA will be held August 3-10, 1976, in Moscow, and the president, Professor Arthur H. Robinson of the University of Wisconsin, will preside. The themes of this meeting will be cartography as a service to public education; mapping of nature and natural resources for environmental protection; the cartographic application of remote sensing data; methods for utilization of maps for scientific research and application; international collaboration in the compilation of small-scale map series; and the development of cartography in Russia and the USSR. Technical exhibitions will include Maps and Atlases for Public Education; Natural Resource Maps and Atlases; Nature and Environmental Protection Maps; Charts of the Continental Shelves; Seas and Oceans Resource Maps; Maps Compiled on the Base of Remote Sensing Data; Maps Published with the Use of Automatic Means and Modern Technology; and Cartographic Literature.

At the Second General Assembly, London, 1964, three working commissions were established. The objectives of Commission I, Training of Cartographers, are (1) to collect information on the different systems of training cartographers, (2) to collate this information according to the various technical and professional levels and age groups of those in training, and (3) to make this information available in a concise and convenient form. The objectives of Commission II, Definition, Classification, and Standardization of Cartographic Terms, are (1) to make a list of terms designating the principal cartographic documents, (2) to make a list of the essential operations involved in the preparation of these documents, and of the terms designating such operations, (3) to prepare a short but sufficient definition of each term chosen for the documents and for the operations, (4) to prepare a classification of maps, charts, and cartographic documents, and (5) to prepare a simplified glossary of the corresponding terms in the principal languages. The objective of Commission III, Automation in Cartography, is to study and evaluate automated aids for the cartographer.

The first two commissions have progressed well in accomplishing their objectives. Commission I has completed two publications on education, and Commission II has published the Multilingual Dictionary of Technical Terms in Cartography with definitions in five languages and corresponding words in nine additional languages. Commission III has not been dormant: it has held a symposium or technical meeting each year since the first one in Frankfurt in 1966 and has published several volumes--Automation: the New Trend in Cartography, the final report on the ICA Commission III scientific working session held August 1973 in Budapest, and Automation Terms in Cartography, definitions of terms unique to automated cartography (copies may be obtained from ACSM). The latter has just been published, but Commission III is already reviewing it to include new terms and definitions. Although the objective of Commission III has been narrowed, its mission is dynamic and will never be completed. The next meeting of Commission III is a symposium to be held at The International Institute for Aerial Survey and Earth Sciences (ITC), Enschede, Netherlands. The topics for discussion are digitizing processing, output techniques, cartographic systems (configurations for all kinds of cartographic purposes), tests for hardware, and trends in hardware and software development. The ICA Working Group on Oceanographic Cartography will share one day of the meeting to discuss automation of marine cartography. It is probably too late to submit a paper for this meeting, but papers will be required for the Moscow meeting.

The most important current project of Commission III is the preparation of a universal test standard that could be used for testing all automated hardware and software. If a common test standard can be agreed on, then claims for digitizing, processing, and output speed and accuracy would be meaningful. Various systems for collection, processing, and output can be checked against known parameters or against each other. Members of the Commission are being supplied test samples so that they may perform the test, evaluate the concept, and recommend any revisions or additions for improving the interim standard. One session in the Netherlands will be devoted to the results obtained by the participating countries.

Over the years 3 additional commissions and 2 working groups have been formed: Commission IV, Thematic Cartography; Commission V, Communication in Cartography; Commission VI, Techniques in Cartography; the Oceanic Cartography Working Group; and the History of Cartography Working Group. The U.S. is represented in each commission and working group. The ACSM

Cartography Division has a U.S. National Committee for ICA responsible for U.S. participation in ICA. The chairman of this committee is Warren Schmidt, 11304 Fieldstone Lane, Reston, Va. 22091. Inquires about U.S. participation in ICA, Commission III should be addressed to Dean Edson, Western Mapping Center, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025. Edson reports that the published record of this week's meeting will be available for discussion and distribution at the Netherlands meeting.

Diello: We (RADC) still consider the test standard experimental. It has not been thoroughly assessed or used enough. However, we have constructed a test to encourage people to think about the uses of a test standard. At the ICA meeting in Madrid two members of Commission III began discussing the advantages and disadvantages of point and stream digitizing. At that time we offered any member of the Commission a copy of the test standard and instructions for compiling data streams in either a point or stream mode. Using our diagnostics at RADC, we promised to assess the test results and to determine which method is most effective from time and accuracy standpoints. We have six test data sets out now; a few more test packages are available. If anyone in the audience wants to participate in this small but meaningful test, we certainly want to hear from you.

Two members of my working group are Dr. Gottschalk from West Germany and Mr. Nardozza from the U.S. Nardozza was the project engineer on the cartographic test standard developed for the Air Force at RADC. I have asked each commission member to identify additional candidates for this working group. We hope to enlarge it to 8 or 10 members, to make it as international as possible, and to have something to report as early as the 1975 spring ITC conference in the Netherlands.

Government and private industry are working together to establish a realistic yet flexible cartographic test standard consistent with the existing and projected requirement of the various mapping and charting communities. The objectives of our working group are to design a standard capability of testing the accuracies, resolution, repeatability, and input/output rates of various graphic digitizing equipment and to intermediately manipulate digital records and ultimately convert them back into manuscript form.

The test standard should be composed of three basic elements. The first is a graphic manuscript exhibiting a wide variety, quality, and density of cartographic features, imaged on a dimensionally stable base material in a form suitable for reproduction. This manuscript should serve as a source bracket for input devices being tested and a reference bracket against which output test materials could be compared. The second element in the test standard is a magnetic tape or digital record containing all the graphic information (registration points, control points, and feature identification) portrayed on the stable base. The third element is analytical software for comparing the digital data with the test standard.

The first step in the development of a cartographic test standard is to develop a design that accommodates the conditions under which the cartographic test standard is to be used in both manufacturing and production. Most testing should be done at individual equipment levels. The cartographic test standard should be capable of determining general performance with defined specifications and required error budgets, lump parametric errors, and limited error diagnostics. It should also identify error budgets based on error threshold, and perform necessary measurements, reduction, and analyses by error analysis software, diagnostic graphics, or manual measurement techniques. Testing should be as simple as possible within normal operator measurement capabilities. The simplest test would probably be an error budget test which might be required for normal setup and checkout.

Periodic testing should be an integral part of the continuing quality control of a preventive maintenance program. Testing is also useful when excessive errors are observed in the normal operation of a device and when a new device is being assessed in comparison to other devices.

I welcome any contributions, ideas, comments, and criticism. For the working group to be effective we must represent the entire international cartographic community. The development of a cartographic test standard will take a few years, and before it is totally accepted, it will have to be thoroughly assessed and certified.

Nardozza: As Diello indicated, the experimental test standard developed at RADC 3 yr ago consists of a graphic portion, a digital portion on tape, and a diagnostic software package.

(Slide) (Editor's note: Slides not available for publication.) The test standard consists of a cartographic composite which was tailored to represent the standard 1:250,000 JOG charts. The features identified as below standard can be added in any of the boxes marked "blank." The basic format is 24 by 36 in, and there are 12 8- by 8-in blocks with a 6- by 6-in information area within each. These areas consist of features selected from the composites, such as nonintersecting features which eliminate software problems associated with scanning through intersections and vertical information which is more acceptable to the scanning devices. We did not want to be totally dependent on the linealization process as a criterion for evaluating the scanning systems.

(Slide) This fiducial construction gives an optical target for hand-held digitizing systems and a unique geometric pattern for recognition by the scanning systems.

(Slide) Our resident glass standard has a series of skewed lines which are not to be digitized but are used to optically evaluate plotted outputs. Most are angled from their center point on a 10 mil/in slope. The standard copy used for digitizing has straight lines between the fiducials. However, if you try to examine the output and distortion of the plotting system by overlaying straight line segments between the fiducials with the skewed lines, you create an optical vernier which gives 50:1 and 100:1 magnification. Thus with a pocket scale you can get an indication of distortions and discrepancies of 20 to 30 mil.

(Slide) One panel consists of a series of radial lines of 4-and 14-mil line weights, which indicate the errors of vector or angular dependence. This panel is useful on both scanning and manual digitizing systems. The 14-mil line weight is used because we feel it is typical of hand-drafted manuscripts.

(Slide) A series of resolution rulings--vertical, horizontal, and skewed--are located in one of the 6- by 6-in information areas. Again, these resolution rulings can be used to check high-speed scanning systems, manual systems, or semiautomatic line-following systems. A series of semicircles of various line weights allow us to obtain some indication of angular dependence and to accurately define the precise intersection of features that converge very slowly.

(Slide) This simple grid localizes any deformation within any one of the 8- by 8-in working blocks.

(Slide) This slide shows a composite that serves many purposes. Not only is it typical of the 1:250,000 but left, right, top, and bottom boundaries match. If you need repetitive information cells or an unlimited data base, you simply repeat and panel the composite as many times and in as many directions as desired. The composite cartographic panel is the test graphic to be used in the digitizing test that Diello mentioned earlier. Approximately 360 lineal inches of feature information are organized into 8 basic classes with 8 unique headers. RADC has used this cartographic portion extensively over the past 3 yr. We developed the standard in order to compare the results of high-speed scanning systems, semiautomatic line-followers, and manual digitizers. Within a working group we found claims of speed, accuracy, and rates that no one was able to duplicate. We use the standard to train operators and to monitor their progress. We can also check experimental devices, which are prone to failure. The test standard is flexible so that test results can be either detailed or cursory.

(Slide) This cartographic composite was digitized from a hand-drafted source. In testing plotting systems, you generate a plot format from the digital file on tape, output that data in graphic form, and compare it with the composite of the standard. You can move through this testing system in many ways, depending on your interest: you can make graphic to graphic comparisons and digital to graphic comparisons.

(Slide) The most important way in which we have used the test standard is to evaluate input digitizing systems.

(Slide) Two stages in our diagnostic software compare the test files with the stored standard file. This slide summarizes what we look for and what we can analyze from the first phase, i.e. Pass 1. The test sample of data obtained in point and stream digitizing modes may be compared to the standard file or to each other. The errors in x and y direction are presented as a collective mean and as orthogonal arithmetic averages which indicate bias. Thus this test can eliminate some machine errors.

(Slide) The significance of this histogram is to show error frequency. Range designates the error interval in 0.001-in steps, and frequency is a scaled representation of the number of errors in each interval.

(Slide) Pass 2 provides a listing from which we can analyze the data point by point. It also provides a line-printer plot of the reference data with the test data. The listing shows the interval between test points, the orientation of line segments between points, their relationship to the reference points, and the value of the x and y bias adjustment necessary to minimize the summary displacement errors generated in Pass 1.

(Slide) One transaction of Pass 2 will provide a line printer plot of a specific feature or portion of a feature. This transaction allows you to use your line printer to rapidly plot a comparison between the test data and the reference data. This capability is particularly useful in analyzing the raster to lineal conversion software that we are developing to support our color scanning system. The succeptability of the algorithms to highly convoluted lines is clearly demonstrated by the Pass 2 output.

(Slide) This slide shows what happens in stream digitization. If you are interested in what an operator is doing and what the data look like, you can specify an area or a portion of a feature and get a line printer output, which gives an all-points consideration of the rms deviation from the true reference point and the intended counterpart (test point) on the line.

The cartographic test standard has been very beneficial. It provides an appropriate way of gaging our progress and a method for assessing the relative value of high-speed scanning systems, high-speed line-following systems, and manual devices.

Gottschalk: Since automation was not used for production until now, sophisticated methods of testing cartographic equipment were not needed. People simply believed what the manufacturers said. With the installation of a system paid for by the German Counselor of Research, test methods were systematically developed.

Scribed words on a thin metal plate are used for testing digitizers. The grid is composed of holes produced by a high-precision tool machine. The grid constant is about 2 in. The coordinates of the grid points used for calibration of the digitizer are measured with a high-precision coordinatograph so that the grid points are known within an accuracy of about 30 µm. The coordinates of the grid points are compared with the readings of the digitizer by lining the metal plate on the digitizer table so that the x values of the map points at the extreme left line of the grid are 0. The y value of the grid point in the lower left corner is also set at 0. The differences between the digitizer readings and the known coordinate of the grid represent the errors of the digitizer. If systematic errors of the whole table are found (for example, different scales in x and y direction and deviation in the angle of the x coordinates from 90 degrees), they must be adjusted in the electronics of the digitizer. The metal plate must be as large as the digitizer table, and its temperature equation must be known.

Another method for testing digitizers is to use a glass plate and measure the coordinates of points of a 10-cm by 10-cm grid. The glass plate is moved systematically, and the measurements are repeated. The coordinates obtained by the different measurements are transformed into one coordinate system by a least-squares adjustment. The relative differences of the coordinates of the transformed measurements indicate systematic errors of the digitizing table. With this method no absolute scale of the grid on the glass plate is needed. The climate must be checked constantly during the test.

A simplification of this test is a test using points in a straight line on a piece of plastic. The coordinates of two points are measured on the digitizing table, and the distance between the points is calculated from coordinate differences in the digitizer system. After changing the direction of the line formed by the two points on the plastic, the measurement is repeated and the distance is recalculated. If the distance has not been changed critically, the difference between the two distances must be due to an error of the digitizer table. Systematic relative errors of the table can also be found by this method, but the absolute scale cannot be determined.

The accuracy of digitizers is also tested by other methods. Usually, correct values of coordinates are compared with the coordinates measured on the digitizer table. The direction of the movement of the cursor is considered. For testing drawing machines, the test of static errors is performed by using a laser and differometer, a rule, and fixed angles.

The main tests evaluate hardware and software. Digitizing is tested with a test pattern digitized from a typical topographic map. The lines are digitized point by point where convenient, elsewhere by stream digitizing. The point rate is about 30 points/sec if the time mode is used and about 10 points/mm if the distance mode is used. Alphanumeric input is generated by the keyboard or manual technique. The digitized data are transformed into a plane coordinate system (like the UTM system), displayed on a CRT, corrected interactively, and listed by the line printer. Many editing functions are used. The digitizing is made on-line and off-line, and the data are processed according to the required purpose. The digitized data are filtered so that only those points are left which are sufficient and necessary for drawing the line. The data to be drawn are optimized so that the drawing machine runs the shortest path. The drawing is done in ink with a scribing and light spot on the tangential control that includes automatic symbolization. Programing and real-time assessing is tested, such as on-line digitizing, drawing, teleprocessing, filtering, and editing at the same time. In addition batch programs are run in the background.

Restart and protection measures will be tested. For example, if there is a power breakdown in the system, the data bases must be protected or reconstructed if they are destroyed. The direction of the data bank in different stages of filing is tested by measuring the processing times. The capacity of the data bank is examined at different stages of solution. The reaction of the data bank to different densities of digitized points is tested too.

As test material, the 1:50,000 German topographic map is digitized in different color separations on film and on paper. The drawing data automatically generalized from 1:50,000 to 1:200,000 are used. The complete test of hardware and software requires 2 months. This test was developed by the Cartographic Research Group of the Institute for Applied Geodesy.

Hoinkes: A small system--hardware and software that includes a multi-activity operating system--will cost about $250,000. We plan to run up to 4 concurrent activities on one PDP 11/40 computer. We have included a variety of peripherals: 12-million 16 bit word disk, 9-track magnetic tape unit, cassette tape unit for smaller files, card reader, printer, and console. The graphic work stations included are two interactive digitizing and/or editing stations. One is equipped with a GRADICON high-precision digitizer for input of graphical data, a keyboard, and a special-function button keyboard where functions can be taught to the system by software. Visual feedback of all input goes to a Tektronix 4014 storage CRT. We will use this station for manual line-following digitizing or point-by-point digitizing. In any case we get an immediate feedback of what has been digitized, even though we may have to process up to 50 points/sec according to the current digitizer calibration derived from 2, 3, or 4 reference points. The points are digitized and transformed immeditately so that we get their transformed (and stored) positions on the CRT. However, x-y cursor lights can show the raw digitizer units, if we like. I call this station a digitizer-editing station because it allows us to use all the editing facilities available (and mainly used) on the other station--a smaller Tektronix 611 CRT with a tablet as a graphical input device (a smaller, less precise digitizer) and a keyboard. Finally, to get hard-copy verification of what has been done on these two stations, we have included a CalComp 936 drum plotter, also on-line, which may run as an independent third activity or in background with another activity. It gives sufficient line quality and precision for check-plots of all digitizing and editing work.

The main problem of computer-aided cartography is input of cartographic data. However, we do not intend to use the system for big digitizing jobs. For this reason, I'd rather call it a digitizer-editing system. We still think that manual digitizing will be used for quite a while, either in editing or generating new lines. When you generalize from an existing map image copied at reduced scale to a scribing sheet, you can not use a scanning or automatic line following device since the line you want is not yet there. It can hardly be generated automatically in the near future. Certainly, when one must input a great amount of graphical data (for example, all the 1:100,000 topographical map sheets of a small country like Switzerland), it won't be feasible to follow all these lines manually. In this case we will have to think big because the volume of the data is tremendous in terms of today's technology. Using many men on manually operated digitizers, as the Ordnance Survey in Britain intends to do, is like cutting trees with pocket knives. It can be done if you use enough people and the famous Swiss army knives, but it would be better to find two strong men with a big saw.

In our small cartography department we do not have this large-volume input problem. Therefore, we will experiment with such editing techniques in which future human judgement and digitizing will be necessary. On the other hand we will have access to off-line high-precision photoplot output (a British-made FERRANTI Masterplotter) in order to prove that the necessary quality for cartographic reproduction and printing can be obtained from a digital system. Actually, this plotter was bought together with the interactive system, but since it will be used only partly for cartographic applications, its price has not been included in the $250,000.

Another problem is the interfacing of an interactive software and hardware system. I stress software because I think interactive systems are basically software systems, although a minimum of suitable hardware must certainly be there with other data base systems on larger computers. For this reason we have also included software to write data on 9-track magnetic tape in ASCII or to read such data (if formatted according to a certain standard) into our interactive system.

The stand-alone interactive system will allow us to work quickly with large amounts of data generated on another computer system. After the tape is read to disk, even millions of data points (which one map sheet may contain) can be displayed on the storage tube in a reasonable time since data transfer rates up to about 100,000 baud are used within the system. After the editing and possibly the plotting have been done, the data can be fed back to the larger computing facility on tape.

Dunphy (Research Facility, Univ. of New Mexico): (To Nardozza) Have you found any trend differences between the distributions you've obtained with point and stream digitizing?

Nardozza: No, we have not attempted to analyze the difference on that basis. That program is just beginning, in fact about 3 wk old.

Dunphy: How many points do you anticipate having to look at to get an idea of the distribution limit?

Nardozza: Our basic manuscript will contain 360 linear in. We haven't identified any restraint in the point mode. Whether it is a random point mode or a time-dependent mode makes no difference; we will compare it to a 1-mil or 0.1-mil standard.

## Outstanding Hardware Problems Panel

A. Raymond Boyle, Presiding
University of Saskatchewan, Canada

W. Howard Carr
U.S. Army Engineer Topographic Laboratories

David W. Rhind
University of Durham, U.K.

Olin Bockes
Soil Conservation Service

Joseph Diello
Rome Air Development Center

Peter G. Wohlmut
i/o Metrics

Boyle: This year interactive graphics editing is moving out of a development phase into users' hands. Also for the first time, professional digitization is not only available, but available on a relatively low-cost contract basis. One of the reasons that I asked Peter Wohlmut to be on the panel is because his company, i/o Metrics, is starting professional contract digitization. Many companies are working in manual interactive contract digitizing.

Important aspects of the state of the art that are still being developed are CRT lightheads for x-y drafting units, interactive geographic information systems, and laser-dot storage disks. The CRT lightheads for x-y drafting units provide enormous flexibility. The range of symbolization of lines, areas, etc. is important. Howard Carr and I are involved in this work and have great hopes for its future. I am pleased to get away from the optical-mechanical system that has served us so well for 10 yr.

The extension of interactive cartographic editing to a full interactive geographic information system should make it possible to analyze the cartographic data associated with various data formats.

The most important development is the laser-dot data storage disk. To me this disk is the true digital map. We were talking yesterday about the large amount of data for World Data Bank III; my calculations indicate that we could get 10 of these banks on one disk. All of the Hydrographic Service information for Canada would go on one disk. But people are becoming worried about confidentiality when you can put all the data for your organization in your pocket. Advantages, however, are great: access time on any disk is about 0.1 sec, and cost is low, about $25,000 for the playback unit. I am advertising for the companies that make the disk unit because I don't want them to be too commercial. Cartographic and geographic information systems need the archival storage that these disks offer.

Carr: Opto-acoustical modulators will soon be competing strongly with cathode ray tubes as drivers for various laser systems. They too have the ability to randomly move a point of laser light in order to draw lines. In the near future it is conceivable that a head will operate as a no-moving-parts plotting device or be capable of mounting on a large precision plotter, such as a Gerber plotter. The absence of mechanical movements will mean higher speed operations. Solid-state, self-scanning arrays offer great potential in image digitizing systems, and we can expect to see them in mapping applications in about 5 yr.

One of the more interesting problems that concerns us today is how to store all of the information that we are currently digitizing. We have considered using the Electron Beam Recorder (EBR) for writing. We are also very interested in the optical data recording device developed by i/o Metrics, which is being demonstrated during this conference. These devices can optically store data in archival form at densities of $10^{10}$ bits/record. Magnetic tapes have problems retaining information over long periods--there is much print-through and loss of data. They are also relatively expensive compared to film and considerably more bulky for storage and mailing.

We have a great deal of hardware under development, but the software packages are just the tip of the iceberg. The newer output or drafting devices are similar in some repects to general-purpose computers that process many kinds of data. For instance, the EBR currently under development at ETL will be capable of drawing linear data in either vector or raster format, producing high-quality continuous-tone photographs, and writing optical digital data as binary bits.

Rhind: In a sense we are regressing in automated cartography by using special-purpose hardware because many of the first developments in automation were on/off machines made to do specific jobs, many of which didn't work too well. One name placement unit, which cost 10,000 pounds, was sold for scrap for 20 pounds without ever being used seriously. This example is bad and times have changed, but building on/off equipment can still be dangerous and expensive. However certain special-purpose hardware could be useful now to reduce effort. For example, with some line-location equipment, hardware rather than software is used to find a feature in the data base and considerably reduces access time. Extending this application makes it possible to think about hardware for polygon overlay. It is equally possible--indeed it exists already--to use hardware for rotation of block diagrams. Many other examples could be given, such as acoustical code entry, which allows digitizing on a semiautomated basis; the operator voices the numbers while digitizing, and the machine decodes them into binary numbers--a nice way of tying in attributes with geometric information.

Apart from yesterday we have discussed only large-scale systems. In universities we have very different problems. They may not be important because there are few cartographers in universities compared to the number in the outside world, but whether important to you or not, we do have problems. They stem almost entirely from the ready availability of computer power: we usually have very limited graphics input and output facilities. In addition, our requirements are more on/off than those of defense mapping agencies. Thus we have a more intractable problem. University cartographers must have a display on which they can compose maps at about the same scale and cost and in the same way that they always have. Thus the role of automated cartography in universities is more limited than it is in defense or civilian topographic mapping agencies.

Bockes: My organization has many field offices, and I am not sure if each one can be equipped with the sophisticated map editing terminals or map editing systems shown at this conference. We will have to consider computer terminals that can display maps and imagery in the same way that our present computer terminals display alphanumeric information in tabular form. Thus, I am considering a system with a large host computer that has a data base available to many local users. Each user normally will use only a very small portion of the data base, but all users must have all data available to them.

In this kind of system we do not need to produce x-y table coordinates or x-y map coordinates. Perhaps we need hardware chips to translate table coordinates into ground coordinates because of the curvature and convergence built into the maps being scanned. Conversely, we need a hardware chip that will turn ground coordinates into the kind of mapping coordinates that the user requires.

Diello: By and large, the developments that we want are in some way or another pursuable. Certainly we must work on input devices, like interactive editing devices, which are largely manually guided and driven and still quite accurate, reliable, and economical. These characteristics are very important if we are going to develop and produce data banks in in the desired quantities. But we should not discount some assistance in line-following to expedite the process. Probably some specialized input devices are worthy of consideration.

Auto-litho scanning recognition equipment should be developed because the lithomap is still the principle source of our data files and is more effective and efficient in exploiting photography. We are automatically using some highly reliable recognition techniques in the process.

Finally there is too little interactive compilation equipment available. We have emphasized too much the interactive rates demanded of this equipment. We can settle for a far less rapid display system and still have an effective compilation capability if we expand the size of the displays, the color renditions, etc.

Very briefly in response to a point Rhind raised--we are presently implementing a promising voice header entry capability on one of our digitizers to reduce this time-consuming portion of digitization.

Wohlmut: Much thought can be given to decreasing digital storage. The useful result will depend on a combination of visual and digital storage. Combinations can be effected that will minimize the total amount of data to be stored and that will be effective and efficient in a running operation or in revising data. Also there may be a way of automating the original surveys. The laser beam deflection systems are so accurate that one can hit an 8-in spot at 400 mi. Maybe a deflection system with a small computer can be put on airplanes or satellites for triangulation purposes.

Broome (Bureau of the Census): For years I have been fascinated with the idea of a cartographer's drafting station with all the resources of a data base at his command--particularly, if it can be in front of him, like a table, and if he can work with instruments that he is used to, similar to a pen. I'd appreciate further comments on this idea since I know that one of the panel members has already discussed its design and possible cost.

Rhind: The drafting station is a problem not so much in hardware, but in user acceptance. The hardware mentioned by Diello is available almost in its entirety for constructing a digital working station analogous to the draftsman's table. Thus availability is not a great problem from what I've seen and heard so far, but convincing people to use it is a different matter. Education is as important as hardware.

Moritz (PRC/Information Sciences Co.): In some ways you can say that the hardware is available, just as you could say 10 or 15 yr ago that computers were available for a price. New developments, such as the i/o Metrics device, and new capabilities in thermal plastic, laser technology, and silicon storage tubes reduce the cost of these theoretical compilation stations. We're now studying the hardware developments required to enable a man to sit at a compilation console and get the data he needs in the formats he needs. In addition to storage, we are also concerned with the display capabilities and the manipulative operations involved. It is still a big guy's system. We're watching very closely to see how soon it might be possible to have such systems available, even on a time-share basis, for the smaller user.

Rockwell (Dept. of Community Affairs): Right now microfilm plotting is a quarter million dollar game with most of the good hardware. It seems possible to build a machine that with slightly less accuracy could give the advantages of microfilmed vector plotting for a tenth of the price. Similarly, better data management is possible--Harvard is attempting to run large programs using a small amount of core so that they can be run on a minicomputer. The opposite process is also possible--increasing the capacity of small processors with the specific notion of processing geographic arrays.

Thompson (USGS): Wohlmut's last suggestion about automating the original surveying procedures is indeed beyond the "perhaps" stage. Several systems are being investigated, and one system, called Auto-Surveyor, which is a further development of the Position and Azimuth Determination System, is being tested this week. This vehicle contains a payload with inertial navigation devices, accelerometers, velocimeters, lasers, etc. Since this system is approaching the accuracy needed in our surveying operations, I agree, Peter, with your suggestion that it is actually in the operation stage.

(Unidentified speaker): Somebody asked a question about the economics of an interactive station. The hardware and software for a small intelligent stand-alone compilation station would cost about $100,000.

Ryan (Calspan Corp.): The oil industry is also interested in such systems. One system currently under development depends on a geophysicist or geologist to interpret seismic data, make maps, and draw conclusions from the basic survey information. Concerning special-purpose hardware, I had expected someone to talk about the "star" and its applications to the cartographic problem.

Chrisman (Harvard Univ.): How effective will associative processors and star matrix operators be in present layouts? The big Central Processing Unit hardware still seems oriented towards matrix operations. I haven't seen it handle interactions between spatial entities. That development in hardware design is in the future. A spatial model will have to be provided through software.

Moritz: The $100,000 figure for a small system is not unrealistic, but people from government circles ought to be aware of the economics of manufacturing. If 30, 40, or 50 potential users are unable to agree, no manufacturer will risk providing the equipment necessary for the money that you have to spend. I'd like to see more communication between the different users. The only way that we're going to reduce the cost of hardware is through bulk economy.

Various polygonal descriptions have been compared with the highly accurate requirements of the Defense Mapping Agency Aeronautical Center. When plotting two points, it doesn't make any difference whether we call the path a line, a straight vector, a squiggle, or a piece of macaroni--we're still going from one point to another. The longer that distance becomes, the more obvious our problem, if we need to go through geographical coordinate frames for commonality on a global basis. For example, because a straight line is in transverse Mercator, it is not necessarily a straight line in elaborate conformal if you're coming back again. Those things that laid nicely right in front of the schoolhouse no longer do so in a different projection system.

While we need high, accurate, and consequently expensive, storage densities, State and local people don't have to worry about geographics because they're in a grid system. Again we're faced with a dichotomy of use--requirements for different storage systems and different digitizing systems. It would be helpful to catalog the requirements of different groups so that maybe the hardware people could develop products for $100,000 that would meet these requirements. However, it would be difficult at this time to include the highly accurate Defense Mapping Agency requirements in such a system.

Regarding Chrisman's point on the associative processor--the star machine has been used very successfully for spatial relationships like weather prediction or atmospheric modeling. Time and time again the machine's intrinsic parallelism, the ability to treat an entire space or entire net of points simultaneously, has proved valuable. You don't have to address the data structure itself; its representation is built into the structure. Although cost savings aren't obvious yet, the star will indeed be a significant time-saving device.

Carr: I would like to go back to Broome's dream of having access to all of the necessary data at one station. The requirement, "all of the necessary data," presupposes a tremendous data bank. So far this discussion has been bouncing back and forth between software and hardware, and we must all be aware that software is dependent on hardware and vice versa. We must have a particular kind of hardware to access a large data base. We can't access what doesn't exist. In the next few years we should consider a modular data base that is used for different purposes. We shouldn't be mixing apples and oranges in these data bases. The commands that tell a plotting mechanism to move to a certain position and to put down a symbol are hardware commands. They can be stored, but they shouldn't be mixed up in a data base that has information for answering questions about soils and climates. The type of data base will affect the type of hardware used to produce a graphic of a certain quality. About 10 yr ago we had to choose between buying a plotter that would produce a quick and dirty copy or buying a more expensive one that would produce more precise graphics. Today since devices, such as the Electron Beam Recorder demonstrated by CBS labs, have the capability of producing both a very quick and a very good product, the speeds for the quick and dirty graphic are now the same as those for the precision and high quality graphic.

Bockes: Many of the comments relate to my suggestion of a cheaper terminal. Concerning Broome's question about an editing station, there are at least three on display this week that are in that category. They may not be optimized for the traditional cartographic draftsman, but they can be. Dr. Rhind's suggestions indicate the need to standardize some of the cartographic procedures. As Chrisman suggested, for a long time some standard cartographic feature capabilities will be in software. I suggested a few standard hardware procedures available now, such as the mathematical translations from table coordinates to map coordinates and back again. I'm not sure whether this firmware will be located at a front-end processer on a host computer so that anybody with a terminal can run through them or whether they will be little chips in their own terminals.

Rockwell: We've heard again and again that there are several different kinds of requirements, but they seem to depend on: first, the output, whether you're interested in high-precision, one-time maps or in many iterations with perhaps slight modifications of output, approaching an interactive line of thinking (analytical geography or whatever purpose), and second, the purpose, whether for example you're concerned with State planning use or environmental design.

Hardware people can't design a machine for a nonexistent market. We must assemble a group of people to nail down the two and three major markets for automated mapmaking. Maybe certain existing hardware with minor modifications would meet needs that haven't yet been articulated. There may be many potential meshes that we haven't discovered because we have not seen how many of our needs overlap. Maybe what we really need is more work in defining goals; perhaps a recommendation of this conference should be that we assemble a group to do just that.

Tsao (Dept. of Natural Resources, Montana): We have a land-use planning group that defines goals and makes suggestions. About 5 to 10 years ago the land-use planners tried to adapt their own methodology to the existing hardware. For example, the printers used the grid system. We made many mistakes because we didn't have design specifications for all purposes. Now we do. Even in the land-use planning group, we have different types of requirements. While local planning requires a very detailed, accurate scale, State-planning accuracy is not as critical, within 40 to 160 acres. Many format specifications within each group already exist; they just need to be cataloged. Since land-use planning specifications have been available for several years, the people just need to get together and not search blindly.

(Unidentified Speaker): Our thinking is still very provincial. We're looking for equipment that effectively allows us to compose maps faster, but with much of the same methodology that we've used for years. Perhaps we need less professionalism. We shouldn't make a drafting station just to satisfy a professional cartographer's whims. We should be developing a process that uses the available tools more effectively. Certainly, some tools should be improved upon, but we should take advantage of what's here. We could do a great deal right now.

Rhind: I certainly wouldn't disagree that hardware is important from all points of view, and I tried to suggest earlier that we should have hardware for polygon overlay and the like. In the final analysis, however, not the capabilities but the people who use them are really important. London has 8,000 land-use sheets. These are updated periodically by different systems throughout the city's boroughs. Some are updated in, 5-yr intervals, some are updated when the people feel like it, and some are updated when an answer is required. If they want to be really sure, do they turn to their geographic information system? No, they send a guy out on a bicycle to check--that way they can rely on the information. A geographic information system is too expensive for them now, with the present technology and the effort that they would have to put into it. Land-use planning is critical and valuable, and theoretically it can be an ideal market for the techniques that we've been hearing about. But on the other hand, you must recognize that even with perfect information, they won't actually use the techniques even if they have the money. In the long run, the human element is a much more serious problem than the one that you've been discussing today.

Finnie (Private consultant): I don't know how the cost of hardware and software is influenced by the requirement for high-quality standards, but it's been a long time since a Class A product has been able to satisfy the metric accuracy requirements for military operations, whether on an intercontinental basis or in a very small area. Military operations require local measurements for tactical purposes, just as a county surveyor does. We have developed formats other than maps or charts for satisfying these accuracy requirements. As an engineer, I found that in mountainous regions I didn't need quite the degree of accuracy of the USGS Class A 1:24:000 maps; on the other hand, in heavily cultured areas I needed greater accuracy. We have systems for acquiring data, for manipulating photography in relation to this data, and for recording this data digitally so that we can provide military or civil customers with highly accurate input, separate or as a product companion. Rather than beginning the studies with hardware, maybe we ought to study accuracy requirements for the products and consider how variations in accuracy requirements influence the cost.

Bockes: It is as dangerous to refer to land use in a general sense as to refer to a map user in a general sense. Regional land-use planning requires one map scale and one accuracy, while local land-use planning requires a much larger scale map and more stringent accuracy. We do not have a definition of the digital accuracy requirements, and we are not producing maps that meet map accuracy needs.

Schweitzer (Bureau of the Census): Our agency has a particular need not so much for highly accurate maps but for current maps. We ought to consider data acquisiton. Wohlmut suggested some automated surveying techniques, and there are other similar techniques that even I used years ago. But we need some way of capturing the synoptic view so that we can tell if change is occurring in, for example, remotely sensed, multispectral data from different passes of a satellite like ERTS or something with a finer resolution. We need to be able to match these data to the same geographic area within the computer and to internally remove image transformation, rotations, and distortions so that we can isolate only those areas of change. Suspicious changes may require some human judgement; someone may have to go to another data source, such as high-altitude infrared photography, to determine the nature of the change. The revised maps may not be highly precise in position, but they are correct concerning what is there, and we need currency. We have been considering output, but we need to consider input if we are to solve this problem.

Diello: Schweitzer is alluding to highly sophisticated systems that provide the ability to detect change through correlation with a new record from another day or with some rigorously controlled data base. A wealth of technology is probably available to provide these capabilities, but much like the digitizing tables, we really can't afford many of them. They are extremely expensive, and probably we should be providing more effective tools to do the job manually. We certainly sympathize with the view and the need, but I don't think that these capabilities will ever be used widely or effectively.

Rockwell: Dr. Wohlmut, can you say something about the mass storage medium that you described Monday?

Wohlmut: It is a packet with a $10^{10}$-bit storage on it. I have one that I can show you after the sessions. A light source shines through this film, the film rotates at a fixed rate, and then a mechanism drives ahead, back and forth. You access any part of the disk in about 0.1 sec.

Rockwell: It is completely random then.

Wohlmut: Yes.

# Software Sessions

## Introduction to Software

Michael McCullagh
University of Nottingham, U.K.

McCullagh: The United States appears very bright to me compared with the U.K. Last year we had a miner strike which led to complete blackness; practically every industrial organization in the country was dark for 8 hours each day. Once again a miner strike seems likely and lights will be going out again, except in the computing and software sectors where development continues unabated, as it should.

Software is generally divided into two categories--systems software and applications software. Systems software includes driving routines and interactive software that handles, for example, movement of the cursor over an interactive screen. The single characteristic for separating these two categories is that systems software is normally written in a very efficient machine language. We heard yesterday about hardware but not about the software that makes the hardware operate. Although there are many people working in systems software, I regard the task as only a small part of the graphics endeavor. The systems software is also likely to be untransferable between centers. This software is obviously completely hardware dependent, because often the computer goes with the hardware.

Applications software, for data bases, data structures, digital terrain models, manipulation, symbology, and information systems for cartographic display, is a rather different set of programs using high-level language. This language, often FORTRAN, is compatible with most machines in the world today. If the programs are written with transferability in mind, they are probably completely compatible except for one or two random factors which always occur. I hope that all types of application software to be discussed today will be FORTRAN and transferable. One of the big problems, despite the fact that I'm European, is that I don't approve of writing in a software language such as ALGOL because it is applied differently throughout the world. FORTRAN does not tend to have this problem as it is pushed by the largest computer manufacturer.

All the sessions today will consider methods that tend to be style dependent. If you have very little data in your data base, say only a few thousand records, it is not worthwhile to move to a superb, automated structure for retrieval. For terrain analysis, unless you have large sets of data and large files which you want to keep in a big memory, you can store information block by block.

The biggest problem with automated cartographic information systems is that information sources are not often in completely readable form and must be made so. You will usually have a scale problem. And will the software be used for research or for production? In one situation you are inundated with data which has to go through the pipeline as fast as possible, clear to the finished map. In another situation you will probably spend far longer processing the data to achieve a specially designed output. Another consideration is the size of the computer at your disposal.

According to my "plastic-bottle" philosophy, there is an ubiquitous computer--a small minicomputer system--which practically any firm or small research organization can afford. Effectively you have a domestic user for your "plastic bottle." The alternative is the large machine which can be equated to the SST--undoubtedly worthwhile, but tremendously expensive, big, complex, and always breaking down; you will have difficulty making it work. In other words, unless you are extremely involved in software operation, you do not want to be concerned with making the computer work; you want to be concerned with the cartography. Perhaps cartographers can now be less dependent on the development of big machines and manage with much smaller machines which are still reasonably fast when compared to standards of 2 or 3 yr ago.

My "plastic bottle," which I use at Nottingham, is in my opinion excellent for research work. It could also be used for production if you improved the peripherals. I think that you will get more for your dollar using the "plastic-bottle" approach rather than the SST-type approach. In terms of graphics, more work (admittedly at a less flashy level) could be accomplished using these basic small computers. The "plastic-bottle" approach also seems to have a grass-roots effect--people who are otherwise unconnected with graphics become more concerned and aware of what you are trying to do. Automated cartography would be ubiquitous.

Lastly I want to discuss the accuracy of graphic designs and how accuracy is affected by different features (in a very broad sense). Accuracy and repeatability are only required where you are producing maps to be used by legal arbiters of boundary disputes. For most other mapping, accuracy of input data is relatively unimportant. The relief representation will look fine, regardless of whether the data are exact or only marginally correct; in fact in many cases you cannot get that accurate data anyway.

(Slide) (Editor's note: Slides not available for publication.) Here is John Friend's idea of accuracy in the 1700's, a time when they believed in making maps look pretty. They also believed in making maps as accurate as possible, and this is the result.

(Slide) Maps produced by the computer can be made to look pretty by adding color--perhaps not like this but appealing to the domestic consumer.

(Slide) This was produced in London by Richard Howthe for geochemistry units--an innovation in using automated cartographic techniques to represent three variables with three different colors. This type of cartography is widely critized but can be used very effectively to illustrate relationships between variables by making them spatially obvious.

(Slide) This is the power spectrum of an image that has been contoured. You want accuracy, and you want to make it look less mundane and less circular, hence the color.

(Slide) This is a graphic for simply representing data. Fairly high inaccuracy can be tolerated. Very little computer time and programing expertise are required to create this type of display. It does, however, lack the appeal of color.

(Slide) Here is a view of two intersecting wave forms. Although the plotter that produced this was cheap and very wobbly and the line density and representation are not what they might be, the addition of color has improved the impression of accuracy.

To summarize I suggest the use of a small machine for developing software and a series of programs which are only as good as you need. Maybe we could see more innovative representations from automated cartographic techniques.

## Cartographic Data Bases Panel

Frederick R. Broome, Presiding
Bureau of the Census

Donald J. Orth
U.S. Geological Survey

Nevaire M. Serrajian
Defense Intelligence Agency

E. Llewellyn Robe
Central Intellignece Agency

Charles Meyers
Department of the Interior

Broom: A data base may take any form, and a cartographic data base is no exception. It can be a table in a book, a photo, a digital file, or a map. The average USGS 7.5-min topographic map has been estimated to have over 100 million bits of information--quite a good-sized data base. The form of the data base is usually dictated by the equipment available and the functions anticipated. The product may be as simple as the answer to "What's the center of Washington, D. C., in latitude and longitude?" or as complex as a map of a city's housing quality.

A later panel will discuss data structures for performing operations on data bases. This panel, however, is an introductory panel with representatives from agencies that have data bases which can be used for cartographic purposes. Regardless of the number of people we have on this panel, some excellent examples of data bases for cartographic activities will undoubtedly be omitted.

Orth: My interest in cartographic data bases is geographic names. Names are essential in making our lives intelligible. Actually nothing really exists for man until he has discovered it and named it; futher-more, names are necessary for communication. Though we tend to take them for granted, names are as important in cartography as in our everyday lives. Features of the landscape have common names, but here we're particularly interested in proper names given to specific features. Names are the language of the map; in fact, I consider names to be part of map symbology.

USGS is presently developing a data base on geographic name information to assist the mapping program and the standardization of geographic names throughout the Federal Government. A small staff assists the U.S. Board on Geographic Names (BGN) in standardizing names for Federal usage. The data base now has only about 13,000 names and attendant data in the system. All of the geographic names for Massachusetts (about 12,000) which appear on maps are in the computer. About 1,000 out of 60,000 BGN decisions made since 1890 have been computerized. We are also in the process of negotiating to computerize about 45,000 Alaska names.

We use the GYPSY system stored in the 360/65 IBM computer on mag disks. The name records are somewhat complex, and although this particular system may be slow by some standards, it certainly has proved useful. Each record includes the name and the kind and size of feature; the location in terms of geographical coordinates, State, county, town, section, township, and range; the map where the name appears; any variant names or BGN decisions; and other descriptors such as elevation and population. Information on the origin of the name can be included. Sometimes the record includes geologic names, although they cannot be retrieved separately. The GYPSY system can be queried for any of these elements or any combinations of elements. Of course the system would be a tremendous tool for standardization of geographic names--the goal of BGN.

Moritz (PRC Information Sciences Co.): What will be the form of the output--hard-copy lists of names or special digital products? Are you considering the possibility of telecommunications for interfacing with other data bases.

Orth: There is the potential for all of these options. For the time being, hard-copy printout is the only output available. I hope that someday this particular data base can be queried by remote equipment. There is no end to the sophistication that could be achieved.

Serrajian: The Defense Intelligence Agency (DIA) has developed numerous standard data elements, largely in the geopolitical area, for the interchange of information. A data element is the primary building block of information in the data system, whether manual or automated, and DIA develops and maintains geopolitical data elements for all the components of the Department of Defense (DoD). An example of a geopolitical data element is "Countries of the World," which includes items such as United States, United Kingdom, and Canada.

Figure 1 shows examples of geopolitical data elements: First, DoD-approved data elements and second, those currently under consideration. A future project, not pictured, is a hierarchial coding system for the rivers of the world. When the geopolitical data elements were developed, a requirement to identify parts of the solar system surfaced; thus the data element "Celestial Body of the Solar System" is included. "Division of the World" represents continents and major water aggregations, while "Waterbody of the World" identifies regions that fit into major water aggregations. The Federal standard, "Countries, Dependencies, and Areas of Special Sovereignty," is the basis of the data element "Countries of the World." "Region of Country" includes geographic regions below the country level which do not have political boundary significance and is designed to be used in the same field as "Countries of the World." "State-Province of a Country" encompasses the entire political land surface of the Earth below the country level; the first-order political subdivision must be linked to its applicable country code to be unique. "International Affiliations" includes such items as NATO, SEATO, and CENTO. "Areas of the World" represents aggregations of countries, but presently is difficult to standardize as everyone categorizes the world differently.

All geographic names used are those approved by the U.S. Board on Geographic Names. When researching each data element, a technical expert is consulted. For information on countries, states, and provinces, the U.S. Department of State is consulted; for waterbodies of the world, the U.S. Navy Oceanographic Office. Although data elements are developed separately, the system design must be considered. Each data element, except for the data chain "States-Provinces of

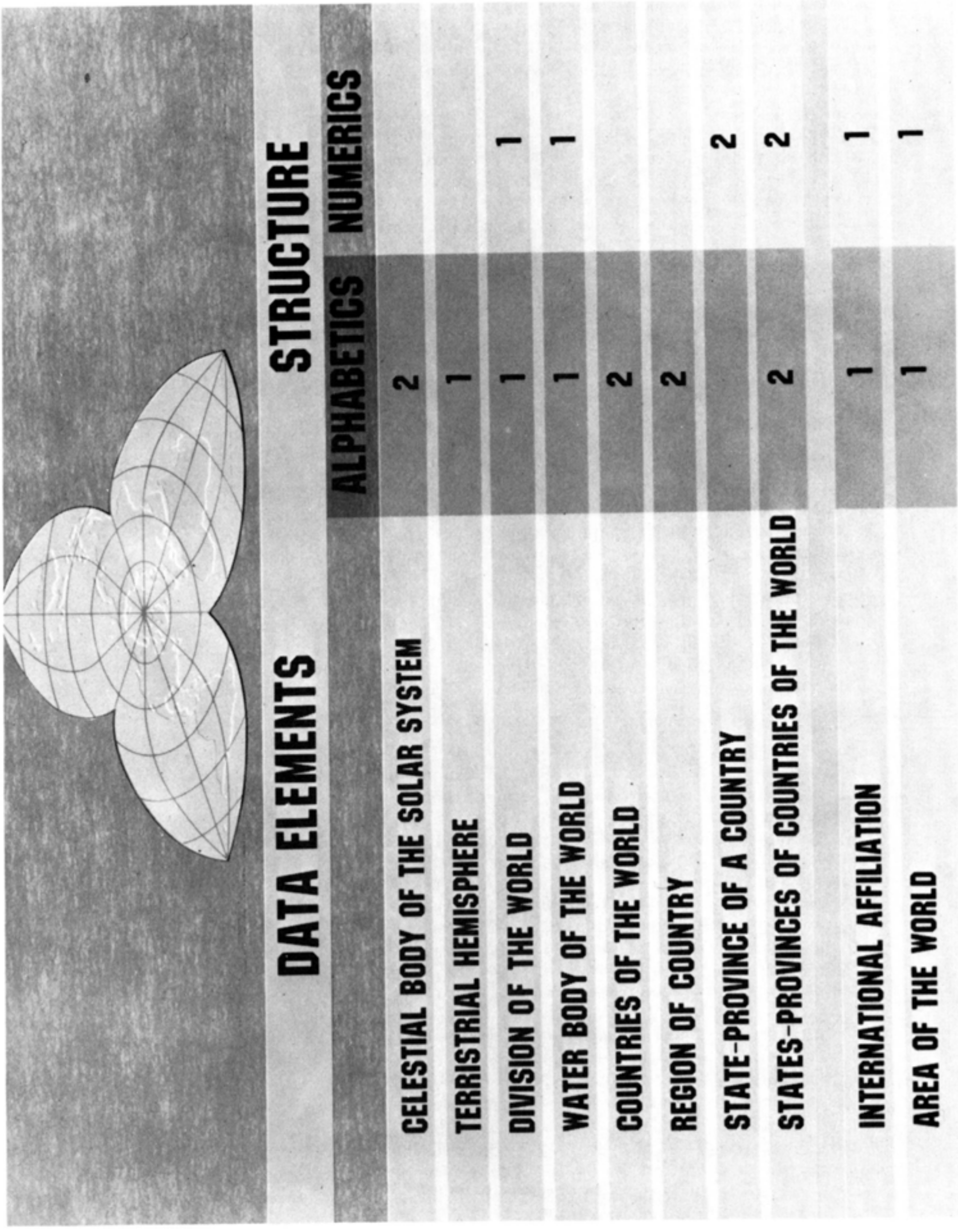

DATA ELEMENTS
STRUCTURE
ALPHABETICS
NUMERICS
CELESTIAL BODY OF THE SOLAR SYSTEM 2
TERRISTRIAL HEMISPHERE 1
DIVISION OF THE WORLD 1 1
WATER BODY OF THE WORLD 1 1
COUNTRIES OF THE WORLD 2
REGION OF COUNTRY 2
STATE-PROVINCE OF A COUNTRY 2
STATES-PROVINCES OF COUNTRIES OF THE WORLD 2 2
INTERNATIONAL AFFILIATION 1 1
AREA OF THE WORLD 1 1

Figure 1

Countries of the World," is identified within two characters. The items of each element are uniquely coded, not only within the parent data elements but within the whole group of geopolitical data elements. If necesssary, all elements can be placed in one field, called a shared field.

A hierarchy of geopolitical data elements (fig. 2) is an alternative to the shared-field concept. The five columns represent five fields in a file--A, B, C, D, and E. In hierarchial order the AA column represents two characters within the field. The data element "State-Province of a Country" normally must be linked to a country code for uniqueness; however, if only one country is being dealt with in a file, the country code is unnecessary and can be omitted. When a file deals with more than one country, the country code is also unnecessary if it already appears in another field within the same record. A minor programing effort could link the two separate fields together.

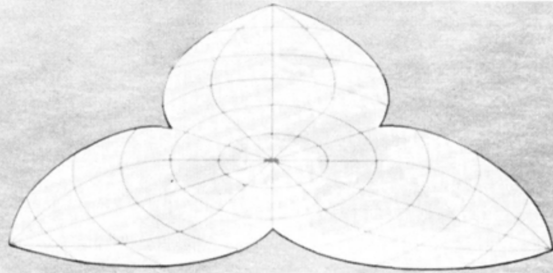
The DIA geopolitical data elements are documented and available through the National Technical Information Service (NTIS) of the U.S. Department of Commerce (fig. 3). A copy of the DIA manual is available for review after this panel. DIA geopolitical standards are presently being proposed as American National Standards. Three standards appeared on the agenda of the International Organization for Standardization which met in Tokyo, Japan, last October. The DIA geopolitical data element manual is revised continually, and as the changes are published, they too are filed with NTIS.

Robe: Unlike my predecessors on this panel, I will discuss a data base that is mainly composed of lines and is plotted. We actually have two such bases: World Data Bank I, simple and quickly generated in 1966, and World Data Bank II, complex but more flexible and more than half completed. Figure 1 illustrates the refinements being incorporated in the newer system.

World Data Bank II, started in August 1971, was conceived as a base for thematic maps. Originally, the plan was to digitize at a larger scale than the desired output scale. Experimenting with some new equipment, however, we digitized one of our more elaborate maps made for another purpose and found that we had the capability to work at 1:1 scale. Since then we have compiled data for 65 percent of the Earth's land area. Very shortly we hope to have digitized all of the world except North America. The data bank now contains about 5 million points; when completed, it will have about 8.5 million points, as compared with 100,000 points in World Data Bank I. The coverage of World Data Bank II was developed as a patchwork (fig. 2), that is, no sheet touching a sheet in progress was begun until the latter was in the bank.

Both of our data banks, as is true of most such banks, were designed to meet our specific needs--primarily bases for thematic overlay data which could be automatically plotted. We wanted flexibility in choosing the output projection and format, independent of the input form. Also we wanted World Data Bank II to have the capability of choosing among several categories of data and of controlling the density of base information. Both data banks can be updated or changed, though not easily.

This portion of a coded worksheet (fig. 3) illustrates the method used to identify the lines in the data bank. (In the original, the information categories were identified by color.) The space problem on the coding sheet reveals one reason why a variety of scales were used.



# GEOPOLITICAL DATA STANDARDS IN HIERARCHICAL ORDER:

| DATA ITEM | COLUMN | | | | |
|---|---|---|---|---|---|
| | AA | B | CC | DD | EE |
| JUPITER | JP | | | | |
| MOON 1-EARTH | EA | | | | |
| EARTH | AA | | | | |
| NORTH AMERICA | | N | | | |
| CANADA | | | | CA | |
| UNITED STATES | | | | US | |
| ALASKA | | | | | 02 |
| VIRGINIA | | | | | 51 |
| NORTH ATLANTIC OCEAN AGGREGATION | | 1 | | | |
| BAFFIN BAY | | | 1P | | |
| GULF OF MEXICO | | | 1M | | |

Figure 2
(Serrajian)

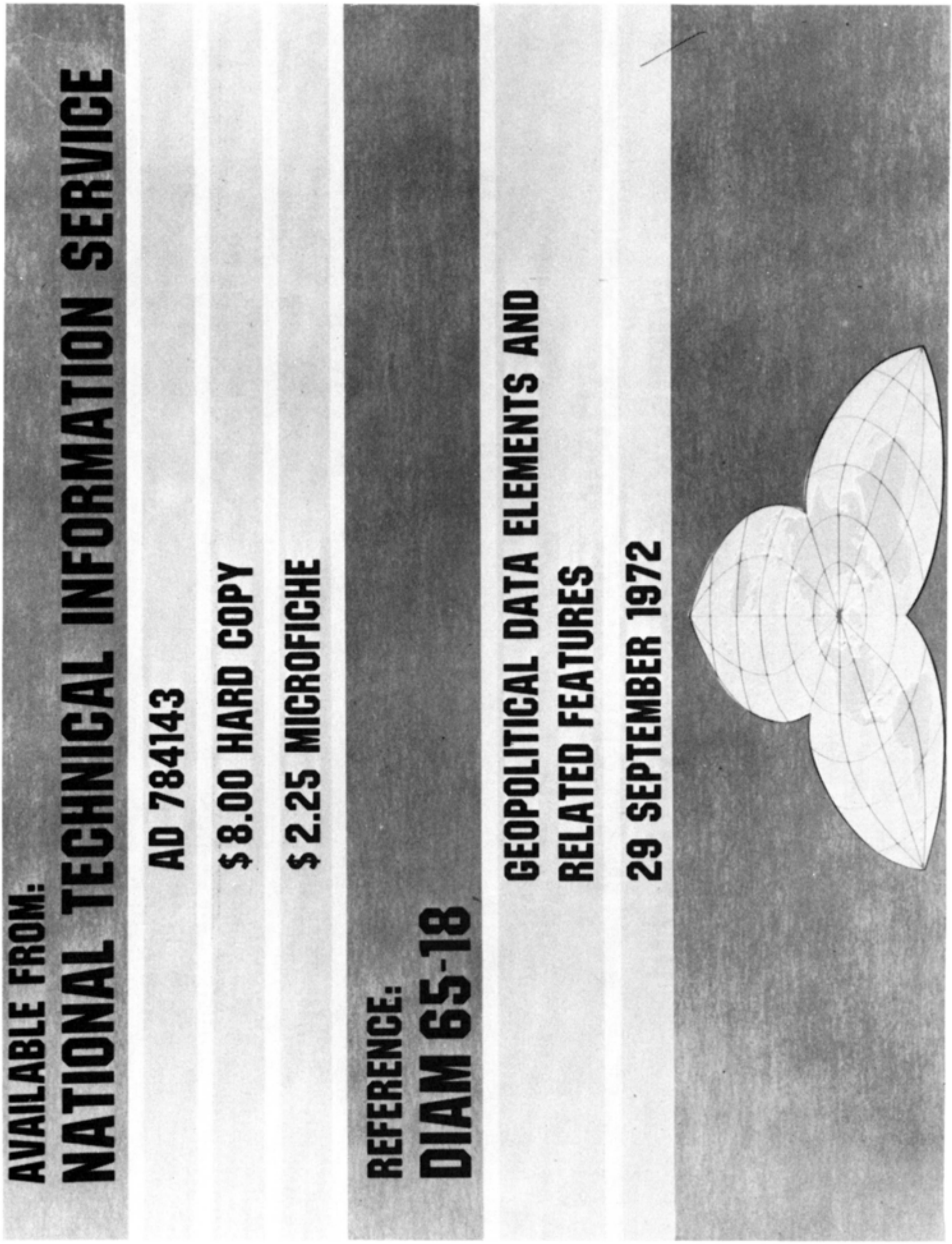



Figure 3
(Serrajian)

WORLD DATA BANKS I & II

**Line Character**

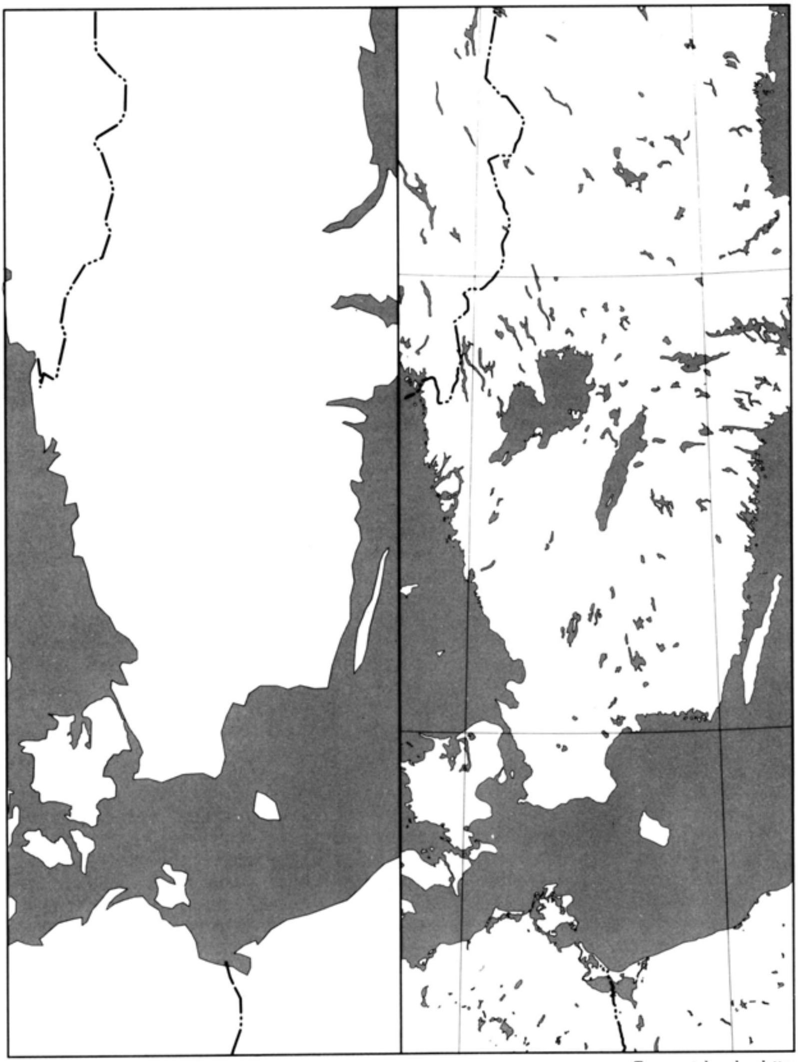



Figure 1

WORLD DATA BANK II

## Coverage

March 1973

November 1973

May 1974

August 1974

December 1974

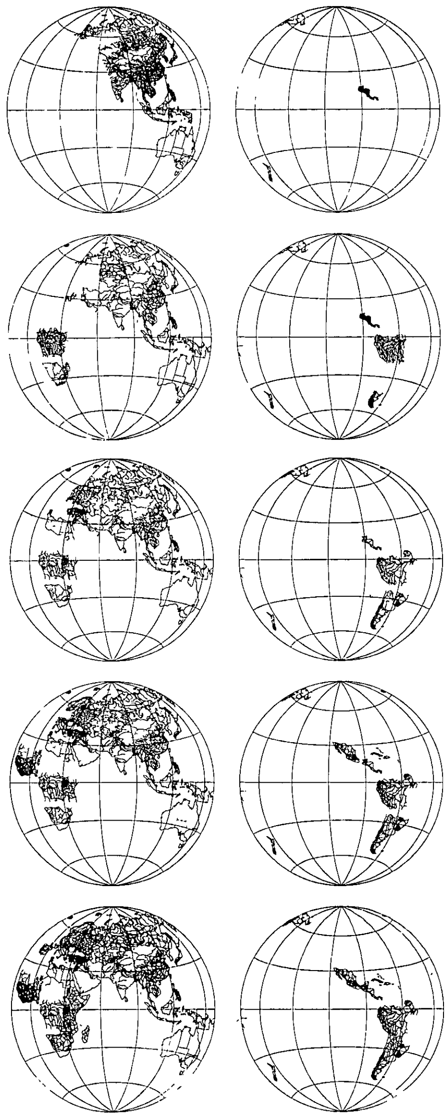


Figure 2

WORLD DATA BANK II

## Coded Worksheet


Figure 3

Since each line must have a unique address in the computer, it is coded with a 9 digit number--7 digits for continent, country, and feature and 2 for rank. (On this worksheet some numbers are abbreviated.) Rank governs the amount of detail shown and enables the compiler to regulate the types of base data to suit the thematic overlays.

Figure 4 shows the distribution of input scales over the world. Most of our map has been digitized at 1:3,000,000. A few very small island groups were digitized at a larger scale. Areas such as Antarctica, Australia, New Zealand, and Siberia, where data are very limited, were processed at 1:4,000,000. This scale speeds plotter time and reduces the amount of storage, but if we were beginning again, we might digitize such areas at 1:3,000,000. Incidentally, the omission of Port Phillip Bay, Australia, has been remedied.

Figure 5 shows an area in which four different input scales were used. Although the computer filters out excess points to make the various sections compatible, the area of 1:4,000,000, plotted at scale, is noticeably less intricate. (The slide reproductions shown are approximately 1:5,000,000.) We discovered very early that no plotted base is absolutely flexible. In the slide of Data Bank I the lines became very angular at 1:4,000,000, 3X the input scale. In contrast Data Bank II holds line quality even beyond 6X although anomalies do occur. For instance, double line streams broaden as scale increases while single line streams do not, giving the map a strange appearance.

The various features of the Data Bank are divided into six different files, five of which are shown on this map (fig. 6), roads are not shown. Each file may be used alone or in combination with the others. Not all categories have been compiled for all areas. The coastline, islands, and lakes are grouped on one file; the rivers and canals are on another. In other files reefs are grouped with islands and glaciers with lakes. This grouping was largely a matter of convenience. To illustrate the variety of possibilities ranking provides, take rivers as an example. This file has 11 possible ranks: 5 for permanent streams, 2 for intermittent streams, and 4 for canals.

As well as providing a choice of scales, projections, and features, these data banks may provide a flexibility of orientation. They may enable cartographers to overcome the "north at the top" syndrome that has been with us since the days of Mercator. Although people seem to accept a computer-plotted map with an unusual orientation, they still expect a hand-drawn map to have north at the top.

Rockwell (Department of Community Affairs): You have said a great deal about the content of the data bank, but very little about its structure. Is the data structure in chains of coordinate points or single points that are somehow identified as connected?

Robe: Since I don't deal with the technical part of the bank, could either Edmondson or Angel answer that question?

Angel (CIA): The data structure is in line chains, identified by a seven digit number. With that number we can pull the line chain out, replace it, or replace part of it.

Rockwell: I believe that those seven digits were described as content identifiers. What is the geocoding mechanism? How do we tie these

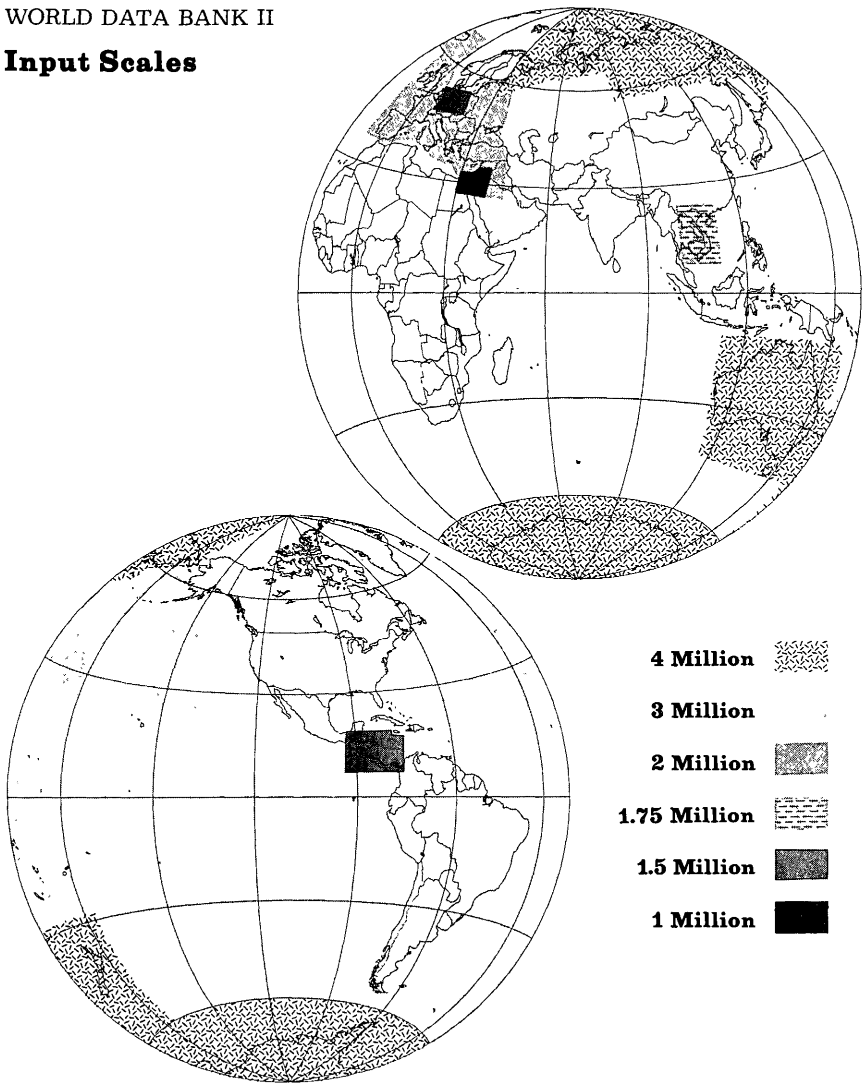
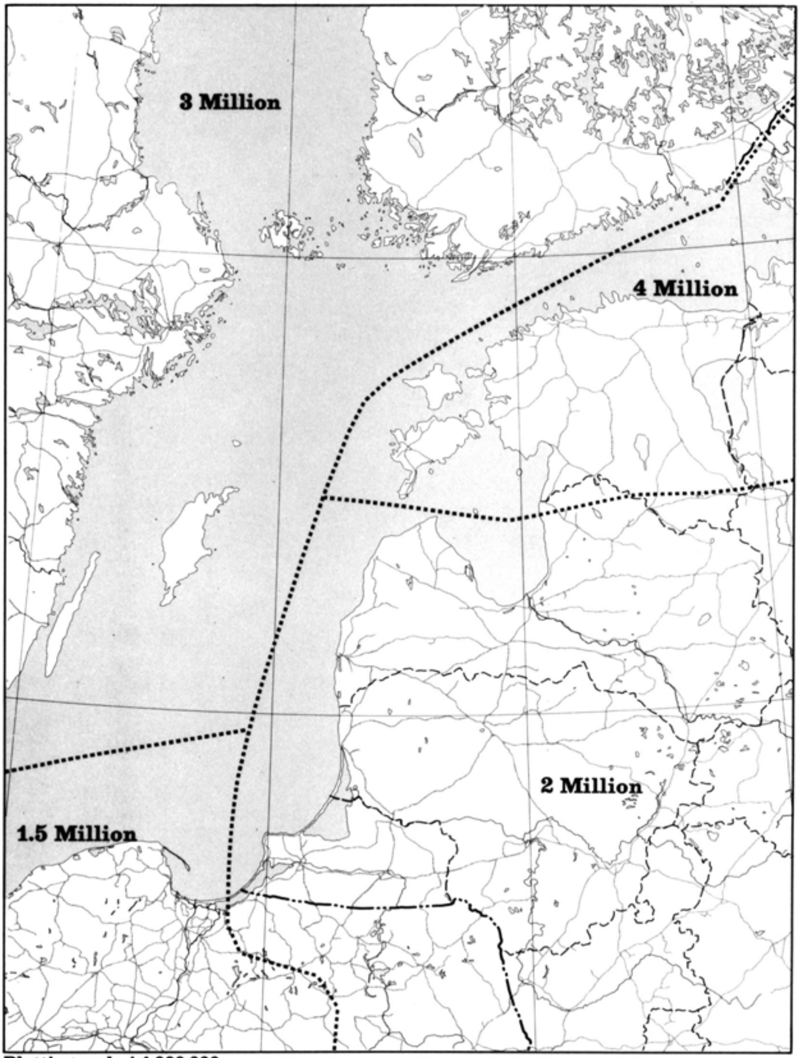

WORLD DATA BANK II
Input Scales
4 Million
3 Million
2 Million
1.75 Million
1.5 Million
1 Million

Figure 4

WORLD DATA BANK II

**Input Scale Merge**

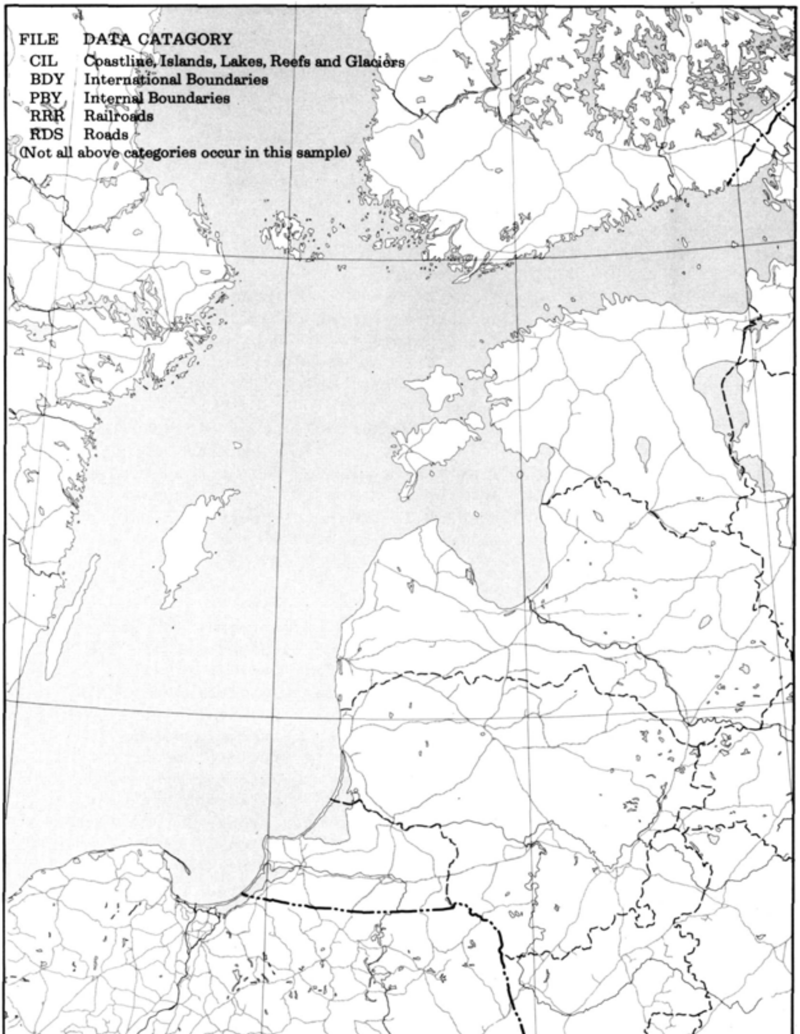



**Plotting scale 1:4,000,000**

Figure 5

WORLD DATA BANK II

**Information Categories**




**Plotting scale 1:4,000,000**

Figure 6

back to UTM?

Angel: Since each line chain is a series of individual points which are in geographic coordinates, they are not tied back in until the actual CAM produces grid. Then the line chains are tied back into the grid at the scale required.

Rhind (Univ. of Durham): World Data Bank II seems very useful. Will it be available through NTIS, and if so when?

Robe: I knew somebody was going to ask that question, and I really can't answer it. Right now World Data Bank II occupies an enormous amount of storage.

Schmidt (U.S. Geological Survey): I believe World Data Bank II will be available in 1975, either through NTIS or NCIC.

Peucker (Simon Fraser Univ.): Working on eastern Australia, we generalized 18,000 points and with an offset of 0.02 in, which is our plotting density, we reduced the points to 1,000 or so. Don't you think that you should reduce the data before distribution? You could reduce your bank to about 500,000 points.

Robe: Undoubtedly we will perform many functions as time goes on because a data bank of this complexity has never existed before. But we are learning as we go. I am sure that much can be done to simplify the use of this data bank; however, I doubt if we will because of the time involved. Once the data bank is complete though, I'm sure there will be people who can and will modify it.

Meyers: Enactment of various Federal and State legislation pertaining to land-use planning will require States to acquire data, conduct land-use inventories, and develop data-handling techniques or processes. Considerable time, effort, and resources are required for any one State to assess its data and inventory needs and to identify feasible alternatives for meeting those needs. Some States have developed highly sophisticated data techniques or centralized processes; others have only single-purpose or decentralized systems or techniques of limited applicability to land-use planning. There is little or no compatibility between States or between State and Federal techniques, processes, or systems. Similarly, there is inadequate and inefficient transfer of knowledge and State experience regarding needs, problems, and feasible solutions. This situation is leading to duplication of effort, massive compilations of unnecessary data, deficiencies in exchange of data due to access problems, and development of data and data-handling techniques that are inadequate for land-use planning and regulation.

The U.S. Department of Interior's Land-Use and Water Planning, in cooperation with the States and under an agreement with the Resources and Land Information program of the Department, has undertaken a study to provide a comprehensive framework from which individual States may assess their information needs and the alternatives for data acquisition and handling. The study has been organized into five tasks:

1.--To survey, evaluate, and report on Federal, State, and key local statutory and U.S. case law related to land-use data and inventory requirements for land-use planning and regulation.

2.--To review data acquisition/handling and land-use inventory systems potentially useful for State land-use planning and regulation; determine the effectiveness of such existing systems; and develop a number of case studies to demonstrate a variety of State experiences.

3.--To identify and demonstrate, through case studies or other means, alternative processes by which States could identify and evaluate their needs for land-use data and inventories.

4.--To identify and evaluate alternative systems for data acquisition/handling and land-use inventories; compare them with existing or pending State and Federal legislative requirements for land-use planning and regulation; and demonstrate, through case studies or other means, how the alternatives may be applied to satisfy State land-use data and inventory needs.

5.--To prepare a handbook for States to use to identify, assess, and develop systems for land-use date acquisition/handling and inventorying.

Workshops are being held at various stages of the project, and a technical steering committee is assisting and reviewing progress.

Results of the study are being documented in several forms: a primer on data handling to support decisionmaking, a handbook on data handling and inventorying primarily for State program personnel, and a series of technical papers ranging from an information systems review to a collection of papers by experts in the field. Publication and distribution of these reports is planned for early fiscal year 1976.

# Cartographic Data Structures Panel

Allan H. Schmidt, Presiding
Harvard University

Nicholas Chrisman
Harvard University

Thomas K. Peucker
Simon Fraser University

Schmidt: A cartographic structure is the organization of machine-readable cartographic data for computer processing. Too often the importance of the structure is misunderstood or ignored. When developing a data file that will output graphic images, it is necessary but not sufficient to have x-y coordinates recorded on punch cards or magnetic tape.

Within the last 10 yr a variety of approaches have been developed to organize machine-readable coordinates for recording and displaying cartographic data. In most cases data prepared for use with one technique are incompatible with data prepared for a different approach or a different graphical display program. There must be a better way to structure a digital cartographic data base--better in terms of having built-in error detection, scale and detail flexibility, efficient use of computer memory, and adaptability to a variety of computer mapping programs.

When evaluating the characteristics of digital cartographic data bases, it is important to distinguish between external and internal data structures. An external data structure is the organization of data on punch cards, magnetic tape, or other machine-readable media external to the core memory of a computer. An internal data structure is the organization of a given set of data within the core memory. The two data structures are clearly related: the internal structure may include information, such as tables or directories, constructed by the external structure software for use in storing and managing the data, but the internal structure can only contain or draw upon information first provided through the external structure. For example, if the topological attributes of cartographic data are not contained within the external structure, the internal processing cannot include operations which require such information.

One cannot create something from nothing (although the reverse is true); therefore, it is extremely important that the initial external data structure for digitizing data should contain all of the information necessary to satisfy anticipated internal and external data structure requirements. At least two interest groups in automated cartography have significantly different requirements--one for planar data and the other for spatial data such as terrain models. This panel will provide an introduction to both types of requirements.

Chrisman: In spite of the broad possibilities of the field, most cartographic information storage systems solve a limited set of problems and are a poor solution to the more general requirements of geographical analysis. To date, few surveys of methods to numerically represent

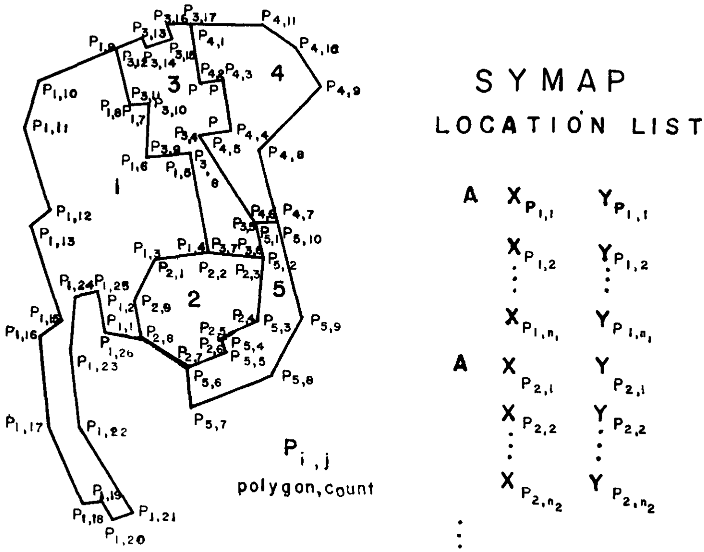



Figure 1

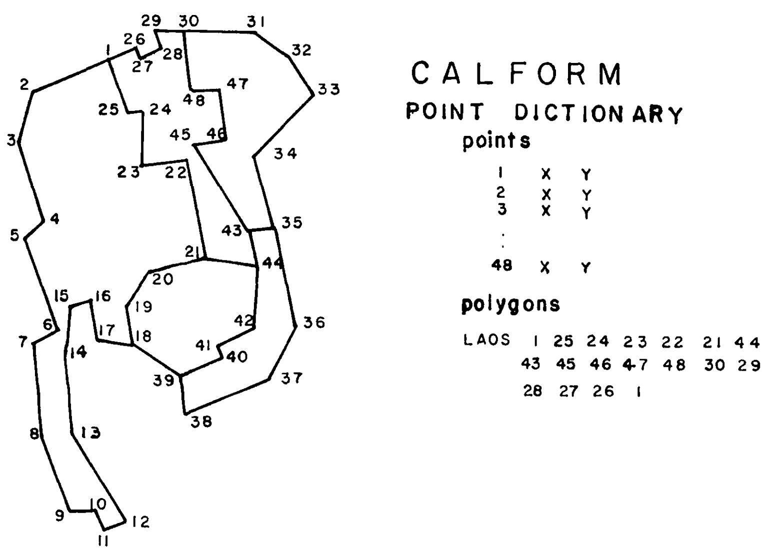



Figure 2

space have demonstrated the impact of a specific method on geographical processing. Some surveys have presented many hypothetical possibilities but have lacked evaluation and comparison with a range of problems (Deucker, 1972). Others dive directly into the question of coordinate storage and ignore the basic issue of what to store (Freeman, 1961 and 1973; Peucker, 1973). Methods of coordinate storage, while important, depend on the design of the data structure, which in turn must respond to the present and future needs of cartography and spatial analysis. I will evaluate a range of widely used systems in terms of their ability to handle progressively difficult problems.

- Cartographic spaghetti--In the development of automated cartography, first priority has been the substitution of mechanical drafting for traditional handicraft. Most large cartographic systems have concentrated on the numerical storage of linear features without any expectation of using the cartographic information as part of a larger geographic information system. The resultant mass of digitized features is often as unstructured as a plate of spaghetti. When plotted, identifiable entities and spatial structures may be evident, but the file contains nothing of the sort. For instance, while a map may show the entity called France, there is no guarantee that the cartographic file contains a distinct France or separate treatment of its boundaries.

World Data Banks I and II typify the substantial investments made in this system of storage (Schmidt, 1969). This data structure is simple and compact, and the size of the file is the sum of the space for coordinates. With such simplicity, almost all file correction and verification must be performed by visual inspection and manual intervention.

- Location lists--The earliest and simplest system for numerical representation of geographic entities is the location list. This system describes an entity by specifying coordinates around its perimeter (fig. 1). A continuing series of cartographic efforts from SYMAP and MAP/MODEL through the Urban Atlas project use this straightforward approach (Arms, 1970; Merrill, 1973; Holmes, 1974). In contrast to cartographic spaghetti, each entity is easily identified in the numerical process as well as in the output. Thematic mapping and other analytical applications are based on the ability to identify individual polygons by location lists, but this ability is bought at the expense of the simplicity and compactness of the spaghetti files. Shared lines between zones are recorded and stored twice, causing knotty problems such as sliver areas and overlaps. Correcting of location lists is not automated in most systems but is a major part of MAP/MODEL and MAPEDIT. Besides causing a correction problem, shared lines also nearly double the size of a location list, thereby expanding external storage requirements; however, only the most detailed cartographic files are limited by this constraint.

- Point dictionary files--Point dictionary files were designed to improve on location lists by establishing unique point identification for the whole file (Peucker and Chrisman, 1974). These files contain a list of the coordinate values for the whole map. Polygons and lines are then built up by referencing the dictionary (fig. 2). The result is a more consistent representation minus the sliver-area problems of the location lists. The "cleaner" output led to its use in a number of plotter mapping programs (for example: CALFORM, Laboratory for Computer Graphics, 1969; INTURMAP, Peucker, 1973; GIMS, Waugh, 1973).

The drawback of the point dictionary lies in its storage requirement, but not in the size of the file on external storage. The storage requirement is somewhat less than that of the location list system because the number of point coordinates is replaced by unique points and the old number of point references. The storage problem arises because the entities are not independent. Point references may be random, forcing the whole dictionary to be core-resident. The storage needed for full cartographic accuracy is prohibitive given present technology.

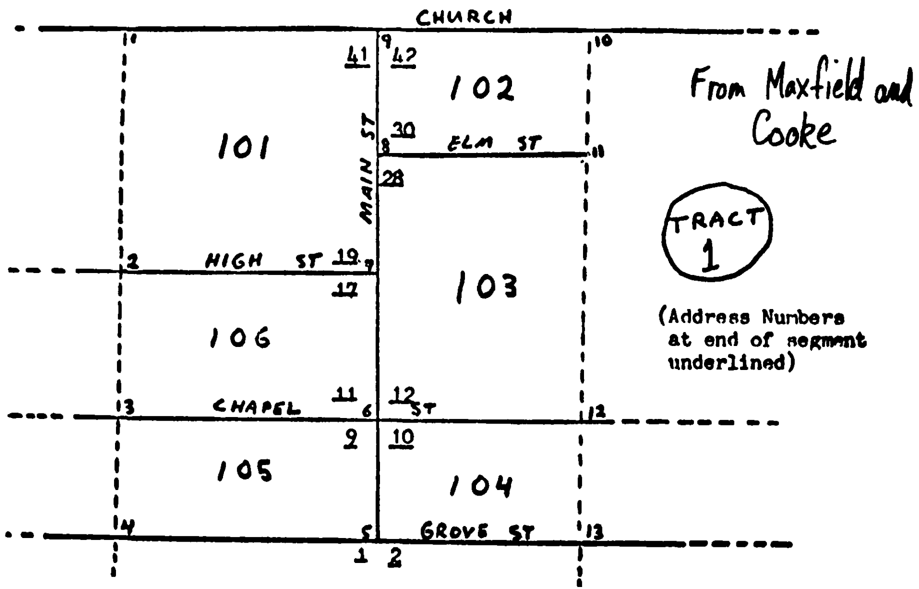
• DIME files--The invention of the Dual Independent Mapping Encoding (DIME) structure by the Census Use Study (Cooke and Maxfield, 1967) signaled a major change in the history of geographic representation. A DIME file does not merely store information about a single targeted entity; features are coded with their topological relationships to other features (fig. 3).

The DIME concept did not spring out of the blue in topological purity. The Census was attempting to organize a mailed self-enumeration in 1970. A system to tie addresses to location descriptors was originally developed as the Address Coding Guide (ACG). It became evident that an ACG was very difficult to verify and impossible to use for graphic display because it contained only streets, not the complete outlines of areas or tracts. By introducing a representation of the connected graph of streets and other features and geographic coordinates, an ACG could be enhanced into a DIME file. The DIME structure allows for topologically based file verification, but the problem of maintenance still remains herculean. A substantial public investment has been channeled into the representation of urban areas, but little cartographic output has resulted.

The mission of the DIME file in the automation of address coding dominates its present form. The unit of storage, the street segment, is small and self-contained. Each segment carries identifiers for a pair of nodes at the ends and a pair of polygon features on either side, plus the address range data. These records are thus fairly bulky. While the segment contains the identifiers of topologically related features, there is no system of directories linking segments together into more complex objects. Due to the fragmentary nature of the file, directories, if created, would be almost as large as the file itself. The file is usually alphabetized by street name to facilitate address matching. Application of the DIME structure to cartographic files has been rare, but the county DIME file is an exception and deserves further investigation.

• Chain files--The chain file, a new structure for representing geographical features, is based on the same topological principles as the DIME system (Laboratory for Computer Graphics, 1974; Peucker and Chrisman, 1974). Whereas the DIME file consists of records that define line segments, the chain file is based on records that define uncrossed boundary lines, each composed of one or many line segments (fig. 4). These boundaries, or chains, connect two end points or nodes and separate two zones. The points between the nodes are cartographically, not topologically, required and thus are subject to line generalization if desired.

The DIME structure, due to its street orientation, ignores the problem of accurate representation of curved boundaries. It is easy to conceive of a DIME application in which 90 percent of the area consists of




**DIME Street Segment Records for Main Street**

| Street | Node(1) | Node(2) | Tract(L) | Block(L) | Tract(R) | Block(R) | Low Add | High Add | |
|---|---|---|---|---|---|---|---|---|---|
| Main St | 5 | 6 | 1 | 105 | 1 | 104 | 1 | 10 | * |
| Main St | 6 | 7 | 1 | 106 | 1 | 103 | 11 | 18 | * |
| Main St | 7 | 8 | 1 | 101 | 1 | 103 | 19 | 29 | * |
| Main St | 8 | 9 | 1 | 101 | 1 | 102 | 30 | 42 | * |

* = Odd left

Figure 3

straight street segments, and the other 10 percent consists of curved features, such as rivers, highways, and suburban streets. If this residual group averaged a modest 10 segments/feature, the total DIME segment file would contain more records from the curved features than from the straight ones. The chain approach groups all the segments of one continuous feature into a single chain. This change makes it possible to approach cartographic files in which 10 segments/feature can be considered small rather than large.

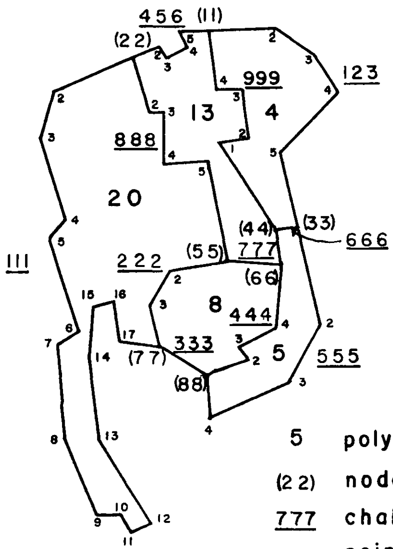
The chain structure can be built from a file as compact as the spaghetti file with the addition of a header for each chain. The header consists of identifiers for the nodes at the two ends and the polygons on the two sides of the chain. Using this information, a set of directories can be constructed to link polygons to their constituent chains or nodes to their incident chains. The space required for these directories is related to the topological complexity of the map, not the cartographic detail. The POLYVART program, a geographic base file converter for which the chain structure was formulated, requires space for all its directories proportional to eight times the number of chains, three times the number of nodes, and twice the number of polygons (fig. 5). Thus to represent the 49 States (plus the District of Columbia) extracted from the County DIME file, the 169 chains and 115 nodes require only 1754 entries of directory space. The original DIME file, perhaps misapplied here, requires 11,372 segment records to perform the same function. Clearly directory building is only practical when boundaries are stored as unified objects.

An extension of the chain structure, due to be implemented over the next year in the GEOGRAF program, will allow for the representation of multiple types of linear and areal features in a single file by expanding the directory system. At the base of the structure the chain and smallest polygon unit will continue to be defined as unbroken linear and areal entities.

PROBLEMS: A discussion of processing problems should demonstrate the relative capabilities of alternative data structures. I will compare the amount of data handled and the storage required, but will avoid chancy comparisons between languages, machines, and installations.

- Line drawing--Production of line drawings is an elementary cartographic requirement and requires little from a data structure, merely the conversion of coordinates into plottable form. Both the spaghetti and chain files insure that each line is processed only once. A DIME file has the same characteristic although random spatial order of the segments reduces plotter efficiency. The location list and point dictionary files are less efficient because shared boundaries are drawn twice.

Frequently a line drawing of a specific part of a file is desired. This part may be specified either by membership in a list of entities or as a coordinate window. All structures except the spaghetti file are capable of inclusion by name or attribute, although the DIME file must be completely scanned for lack of directories. Windowing, however, can be performed with all the structures specified. In the simplest case, the whole file must be scanned to extract the coordinates to include in the window. Any file with objects bigger than a line segment could employ a previously calculated window for each file element. Nevertheless, every object's window must be checked. Further reduction of windowing costs would involve the intersection of a window polygon




## POLYVRT

### CHAIN FILE (EXTERNAL)

| CHAIN | LENGTH | FROM | TO | LEFT | RIGHT |
|---|---|---|---|---|---|
| 111 | 18 | 22 | 77 | 20 | 0 |
| | $X_1\ Y_1\ \ldots\ X_{18}\ Y_{18}$ | | | | |
| 999 | 5 | 44 | 11 | 13 | 4 |
| | $X_1\ Y_1\ .\ X_5\ Y_5$ | | | | |
| 222 | 4 | 55 | 77 | 8 | 20 |
| | $X_1\ Y_1\ \ldots\ X_4\ Y_4$ | | | | |

5 polygons

(22) nodes

777 chains

3 point within chain

Figure 4

## POLYVRT CHAIN STRUCTURE (INTERNAL)

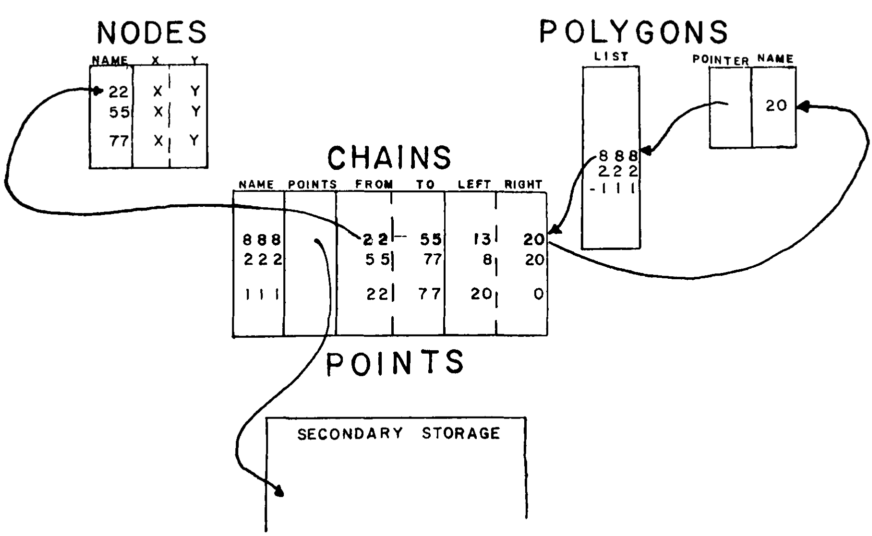



Figure 5

with the rest of the file. A single chain, intersected with a file, could generate markings on all objects within the window at a cost below checking every chain for plotting. Arbitrary windows would then be as easy as rectangular shapes, allowing clipping of files in geodetic form before projection. In practice only the chain file is capable of performing this task at a lower cost than checking every entity's window.

• Retrieving polygon outlines--The problem of assembling the coordinates that define the boundaries of a specific polygon may not occur frequently, but the capability is fundamental in modular systems. Both the location-list and point-dictionary files are designed specifically to serve this need. Since the chain structure includes a polygon directory, the constituent chains can be retrieved, then copied to form the polygon outline. By contrast, the construction of a polygon outline can be costly in the DIME structure. The entire file must be examined to extract segments with the required polygon on either left or right, and then the result must be linked together. By introducing more frequent attempts to link results, the average scan of the file can be reduced, as long as the polygons are single closed entities without islands.

The spaghetti file is unable to retrieve a polygon outline without considerable outside intervention because there is no identification of named polygons and no assurance that any file entity corresponds to a boundary. For this reason the spaghetti structure will not be discussed further.

• Computing areas--The areas of polygons represent a range of geometrical quantities inherent in a cartographic file. Area is computed by summing areas of trapezoids under line segments or of triangles from the Cartesian origin. Thus the general problem is, at the minimum, proportionate to the number of segments in a file. Computing the sums for all the polygons requires duplicate calculations for shared segments. Given the chain structure, the sums for each chain could be added. But if the chains tend to be more complex than straight lines, there would be a significant reduction in processing efficiency; the additional storage of one word per chain, not a great hardship, will improve the efficiency.

Areas can be calculated from DIME files, but neither of the above methods can be transferred. The direct polygon method would require as many passes through the file as there are polygons. The chain approach depends on a directory system and the compaction of chain storage. The best solution would be to read the whole DIME file and generate two records/segment on a scratch file. The scratch records would contain the summation for the segment and either the left or the right polygon identifier; the summation would have opposite signs for the two sides. At the end of the input file, the scratch file will contain double the number of records on the original file. By sorting this file according to the polygon identifier, all sums for a polygon would become contiguous. The sorted output can be read, and polygon areas computed. This process involves not merely the single pass through the source file, but also the writing and rereading of two files of twice the original length (admittedly in shorter records). Furthermore, file sorting is never inexpensive. Computing areas from the DIME file is more expensive than computing from any other data structure.

• Contiguity--Context is the cornerstone of microspatial analysis. Without knowledge of its neighbors each polygon might as well be an independent "spaceship" (Berry, 1973). Despite the growing awareness of contiguity in analytical research, the extraction of contiguity and other analytical data from cartographic base files is not yet general practice because of the complexity of the task. The determination of polygons contiguous to a given polygon is the key to the analytical application of cartographic information.

Only one structure presented here can extract contiguity easily and quickly. Using the polygon-to-chain directory of the chain file, one need only examine the chains forming the central polygon and then collect a list of the polygons to either side. The DIME file also contains contiguity in the left and right codings of each segment, but for lack of directories, a scan of the complete file is required, which is identical to the process of collecting the polygon outline.

Contiguity can be ascertained in a roundabout way from the point dictionary structure if it is properly coded. To find the polygons contiguous to a central one, scan the other polygons for the recurrence of each pair of point references in the central polygon. An optimization can occur once a match is found by attempting to follow the shared boundary (Evey and Mantey, 1974). The number of comparisons will remain proportional to the square of the number of point references, hardly desirable.

Determination of contiguity from the location-list structure resembles the point-dictionary problem, except the coordinate equality test replaces the point reference equality test. Since coordinates can not be expected to match exactly, more costly tolerance-based checks must be used. Unfortunately the use of tolerances can produce undesirable results when different points are closer than the tolerance.

The method described above is only possible if shared lines are coded similarly on either side, a faulty assumption in most cases. In figure 6 the side of polygon C may be coded in either system as extending from point 1 directly to point 3, because point 2 is colinear or nearly so. The MAP/MODEL package, among other features, provides a mechanism to correct these errors in location-list structures (Arms, 1970). The segments are first identified by their center, and a match is attempted. More rigorous matching and correction is performed until every segment's duplicate has been found or broken out of another segment. This process requires the definition of a hull polygon so that the outside edge is also duplicated. In general the computation involved in matching segments greatly increases the process previously described. The economics of contiguity is entirely different for topological and non-topological systems.

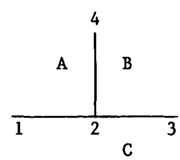


Figure 6

• Polygon overlay--Perhaps the largest analytical use of geographic base files is the comparison of different sets of polygon zones. Most frequently, different variables relate to disparate entities and are thus not easily reconciled. By overlaying and creating an intersection set, an automated process can replace visual inspection as the basic tool of spatial correlation. Furthermore, contiguity statistics will be greatly enhanced when not restricted to information gathered by a single class of polygons. The most pervasive approach to polygon overlay ignores the use of cartographic base files and utilizes uniform grids.

The grid system forces a nasty choice between enormous bulk and resolution inaccuracies. Once a grid is defined, all data must be related to it, and flexibility is limited. The grid system survives not because of its virtues, but because the polygon-based methods of overlay have been expensive.

The overlay of polygons from the location-list structure is performed by MAP/MODEL and many other systems. Every approach reduces to the intersection of each line segment in each polygon of set A with the line segments of the polygons in set B. By using coordinate windows for the polygons in set B, the amount of calculation can be reduced. The time required is proportional to the number of polygons in set A times a subset of the total segments in set B. The size of this subset is determined by the window elimination; the set is smaller for square polygons than for arbitrary shapes. Due to the nature of the shared lines between zones, every boundary intersection must be found twice, once for each side. This solution to polygon intersection makes the best of a limited data structure, but it is expensive when applied to files with many zones or with detailed outlines.

The DIME system is not designed to perform polygon intersections, since it is based on the storage of the smallest urban unit. However, someone will always find a reason to subdivide a unit, no matter how small. The assessor's files of land ownership are an important set of polygons below the block level. Lack of directories makes the economics of overlaying DIME files similar to those of the grid system. The elimination of duplicated lines will be offset by the lack of an entity on which to base window elimination.

Polygon overlay based on the chain structure is remarkably different. The intersection process can be guided by contiguity information to limit calculations. Once a starting point is established, each chain can be treated by using a depth-first search procedure. Depth-first search means that the starting point of each chain will always be known in terms of its location in the other set of polygons and chains. The intersection of each chain can thus be limited to the single polygon it splits. When the chain crosses a polygon boundary, the current polygon is set to the one on the other side. This technique, described in more detail in figure 7, demonstrates the power of topological information in handling complex problems. Only one object in the first set, the starting node, is checked against the whole of the other file. All the coordinate information in the chains is checked only against the polygon currently occupied. With reasonable shortcuts, such as using chain windows in the intersection process, the savings will be great. Additional storage for this algorithm is required for "status flags," for objects processed, and for the stack of the search procedure. Whereas the polygon-based methods involved the multiplication of terms to yield time, this method is not inflated as the files become bigger. The time bound of the algorithm in figure 7 is proportional to the number of chains in the first file and the complexity of polygons in the second. Large files may thus be processed without undue increase in cost.

The problems presented range from line drawings where geographical entities can be distinguished by the human eye to polygon overlay where the automated process must understand the full network of spatial interactions. In the simpler tasks the savings introduced by a complete topological structure are not startling. The first advantage discovered was the ability to retrieve more than one type of entity. As processing developed a greater need for full geographic representation, the gap

## An Algorithm for Polygon Intersection

Given: two chain files, set A and set B.

Find by coordinate comparison the object in B overlaying ROOT, an arbitrary node in A. This node is the root of a depth first search which drives the process. Initialize stack for search procedure with ROOT and its associated object in B.

```
while node stack non-empty do begin
   if all chains incident at node ATTOP done then
           pop node stack else
           begin
           CA := clockwise-most undone chain incident at ATTOP;
           POSIT := object in B overlaid by ATTOP
           while segments left in CA do
              begin
              if POSIT is a node then
                  begin
                    decide which chains in B CA falls between;
                    PB := polygon between chains bracketing CA;
                  end; comment node incidence reduced to polygon
               if POSIT is a chain CB then
                   while POSIT=CB do begin
                       if segment of CA departs from CB
                          then POSIT := side of deviation
                          else next segment
                   end;
               if POSIT is a polygon then PB := POSIT
               assemble chains surrounding PB
               mark PB split
               while POSIT = PB do begin
                   if segment still inside PB then next segment
                       else begin; comment found intersection
                           mark intersection; mark CB split;
                           POSIT := object at intersection;
                       end;
               end;
           associate POSIT with GOTTO,  terminal node of  CA
           mark CA done
           if GOTTO not marked reached
               then begin
                 mark GOTTO reached
                 push GOTTO onto node stack
               end;
end;
```

all polygons in B not marked split can be assigned the A polygon of a neighbor

Figure 7

widened. In the final problem of polygon overlay, the chain-based algorithm registers very significant reductions in processing costs. The increased complexity of the chain file creates a sensitivity to geographic representation. The resulting efficiency can not be ignored.

In cartography the computer should not be used merely to emulate the operation of a draftsman. Cartographic data bases should provide a means for analyzing geographic information. Statistical and cartographic information should be linked to allow thematic and other analyses; the cartographic file should provide a model of the area for the analyses. Relationships between areas in topological structures are vital to both cartographic efficiency and analytic acuity.

Peucker: I would like to trace the discussion of cartographic data structures back to 1967 when Boehm wrote his important but often overlooked article comparing several surface encoding procedures. Surfaces were coded by two similar types of contour storage, the regular grid and a rectangular grid with varying mesh width. The objective of the research was to find optimum systems for data compaction and manipulation. The study showed that the variable grid, or contours, enabled the highest data compression but also resulted in the highest manipulation expenses. The regular grid, on the other hand, was fast to use but voluminous to store. The conclusion--to use one grid for storage and another for manipulation of the surface--is impossible since converting (by interpolating) the surface from its first to its second definition is one of the most time-consuming procedures. The solution must be found elsewhere. Unfortunately, Boehm minimally explored the reasons why opposite approaches gave optimum performance for the two criteria given, and few followed in his steps. This neglect most likely accounts for the relatively slow development of more sophisticated data structures in computer cartography.

Three aspects of surfaces and points on surfaces influence the storage of the surface. The first factor is surface behavior, the average change in height over space. The surface changes from area to area (i.e., it is nonstationary) and with it changes the density of points required to maintain a constant error term for the estimation of a point. Contours adapt to the changing sampling density; regular grids do not.

The second factor is the topology of the surface points. For most manipulations of surface data, a knowledge of the internal connections is necessary. Topology is defined implicitly in the regular grid: the location of a point within the set (matrix) of points simultaneously gives its neighbors. A system of contours, on the other hand, makes it very difficult to find any neighboring points except the two on the same level. All other points require laborious searches through adjacent contours. Other search routines are needed to find a given number of closest points for the interpolation of an irregular grid of points.

The third factor is the relation of sampling points to the surface. One can distinguish between surface-random and surface-specific points. The first does not give any information about the surface beyond their own height. The second allows estimations about the neighborhood of the points and represents certain types of points or lines on the surface breaks. Clearly, encoding the same number of points of each type will result in higher accuracy with surface-specific points.

These three concepts are a good basis for comparing surface information systems, or digital terrain models. The most frequently used data structure is the regular grid. The surface is sampled at regular distances in an orthogonal network. The regular grid is the most efficient data structure for defining the internal topology of the surface points: neighborhood relationships are implicitly defined by the regularity of the grid. However, the structure performs very badly with respect to the other two components of a surface. To maintain a certain error variance the mesh of the grid has be to adjusted to the roughest terrain and thus results in a high redundancy of surface definition in less undulated terrain. Also, it is highly probable that surface-specific points and lines will fall between grid points and therefore the representation of the points of highest information content is very poor.

Data redundancy could be reduced by using a regular grid of varying mesh widths and adjusting the grid density to the roughness of the terrain. Additional computations necessary to adjust to the variation of the density should not be too high nor the programing too difficult. But little work has been done in this area, and only one attempt is described in the literature (Boehm, 1967). This structure would probably have a higher chance of missing surface-specific points and lines than the regular grid.

Systems based on contour encoding adapt readily to the irregularity of the surface. Therefore, the storage density is proportional to the roughness of the terrain. However, this system is very clumsy for the definition of neighborhood relationships and thus for an efficient manipulation of the data. To find neighbors one must search along contour lines above and below the present contour level until the closest points on neighboring contours are found. The process reveals information such as slope and direction of ascent. This system is not very efficient in the representation of surface-specific points and lines, although ridges and rivers are represented quite well in fluvial systems where changes in contour direction are very sudden; in addition neither surface-specific points nor gradual changes in terrain are covered.

When selected to recognize surface-specific points and lines, irregular points adapt quite well to the roughness of terrain. However, a topographic structure has to be explicitly included in the data base. In our research a file has been added to the point file which gives for every point the appropriate labels of all neighboring points.

Aangeenbrug (U.S. Bureau of Census): I don′t think that it would be very fruitful at this meeting to continue confusing cartographers. I would like to comment on some of the topics discussed by Chrisman. First, some of the statements about DIME are confusing to me, and I′m somewhat familiar with DIME. DIME is a generic principle that has been described in the literature. The Geographic Base File (GBF) DIME system is an administrative file structure that many metropolitan areas have. Our concern, however, is the dual incidence, or matrix, coding system, which has many properties that apparently I′ve denied it. Several of the papers concerning these properties will be available tomorrow. One paper, entitled "Arithmecon," describes the multidimensional option of dual-incidence encoding that Corbett is working on. You must be careful not to confuse the operating file system and DIME. DIME is a conceptual model. DIME files themselves are an extension of these models, and there are many types. It′s not really relevant to focus one′s remarks without more substantiation. I would like to alleviate this problem by providing literature and a chance for some of you to meet with Corbett and Farnsworth, who have more experience in these areas. There just isn't enough money in urban areas in this nation for ego trips. Too much selling is going on here. I'm much more interested in learning and understanding.

Chrisman: Sir, I'm very sensitive to your feeling that I'm trying to sell something; I am not trying to sell my ego. I have nothing to gain, nothing to lose. I've attempted to establish my concept of the DIME file from all the DIME files that I've seen. The crucial difference between the DIME file and a system of more cartographic ability is the move away from storing separate two-point line segments. Only a very rare cartographic file has many boundaries which are only two-point line segments. I admit that the more complicated topological structure that I'm presenting has evolved from the DIME file. But to get an explicit topology, you can not be continually burdened by a system based on single segment entities. Perhaps I'm making a distinction between DIME in its actual form for present use and DIME as a topological theory for special representation. I am borrowing the topological system for special representation, but I'm sure that the Census Bureau is working on it. What I'm presenting here as the chain structure seems to be the arc structure that USGS is working on, which resembles the system that Raytheon developed.

Aangeenbrug: To clarify, I'm much more concerned with theoretical implications. The working files are, I admit, primarily administrative files, but the DIME file is generically a set of vertices that define boundaries and coboundaries.

Peucker: But that's topology.

Chrisman: To make the DIME file an analytical tool, one must have access not just to the vertices, but to the vertices from the nodes, from the polygons, and from a set of directories of larger chains based on the small chains.

Tsao (Dept. of Natural Resources, Montana): I would like to comment from the user's viewpoint on what these gentlemen have discussed. We tried to develop a system in Montana, called Environmental Resource Geode Information System (EVRGIS), for land-use planning only. This system has four subsystems--data input, data storage, data output and retrieval, and data manipulation. The most important subsystem is data manipulation. You must consider purpose as well as input and output. We are using the microcell rad system for transmitting corridor selections. For example, with a scan resolution of 0.02 in, the cell size is about 50 ft square, and the transmission corridor is 300 ft wide. For transmission the grid system is much better than the polygon system. We tried the polygon system with an overlay, a 12-in-square map, and it took at least 10 min of Central-Processing-Unit time to superimpose one map on another. But the microcell approach takes only 10 to 20 sec.

Chrisman: How many cells do you have for Montana if you use a 50-ft cell?

Tsao: Montana is about 147,000 $mi^2$.

Chrisman: Yes, but you're storing 50-ft cells.

Tsao: The data are compressed without any problems. Using a study area of about 60,000 $mi^2$ mapped at a scale of 1 in to 2 mi, we stored the data on tape using code compression. Each type of data is stored separately so that it is easily retrieved and doesn't get mixed up.

Chrisman: I agree that overlays should be stored separately, but I still think that we have new efficient algorithms for polygon overlay.

Rhind (Univ. of Durham, U.K.): Unfortunately we are often stuck with divisions of our data. We frequently, certainly in the U.K., don't have the choice of using grids or irregular areas. Thus we must have both capabilities. Grid data have just as many disadvantages as advantages. And in overlaying polygons of any kind or shape, you make assumptions about the internal homogeneity of the data distributions.

Chrisman: You're making the same assumptions with the grid system.

Rhind: I agree. But I think that often the errors attendant in the grid system are greater than those in the polygon system. This point cannot be proved; that's why I'm making it now. You can't decide what kind of data structure to use without considering the tasks to be performed. You must consider what kinds of data access you will require.

We might discuss three types of data access. Access methods for much cartographic data, pantograph representations particularly, have been straight sequential methods. With geographic processing we have a predefined aim. For example, (I'll take the grid square case because it is simple) to define population within 5 km of each point in D.C., you go to each point and look around it. The same process is used for contouring. In using the sector typefaces, you look at eight different sectors. Before you start you know that you must look geographically at all the points or at a selected subset of the points. The most complicated kind of accessing involves many more pointers and looking up the data, going to one particular point, and choosing outwards from that point depending on what you find in the data. If you are looking for high densities of population and you do not want to build on the basis of administrative boundaries, then you have an accessing problem in which many pointers are needed to be efficient. Obviously, we can't have an all-singing all-dancing system without dreadful inefficiencies. A great deal of careful planning is necessary to set up these structures.

Dobson (State Univ. of New York): I am probably a strange creature in the audience because I'm a cartographer. I have used pen and ink and have scribed. People who talk about cartographic spaghetti, problems of lack of structure, polygon files with cartographic ability, and cartographic data should realize that many people in the audience are unaware of some of these matters. We are more excited about what the product looks like than about statistical or mathematical manipulations or probabilties. Many people seem to be picking on World Data Bank I, a damn fine tool. I think you are getting confused about objectives and semantics. Consider, for example, "cartographic ability"; I don't know how a polygon has cartographic ability.

(Unidentified speaker): Come to our workshop. We have this structure working for interactive mapping with World Data Bank I. The output was generated from the metropolitan DIME files and the county DIME files. The present structure of World Data Bank I does not support interactive mapping, but we can perform this task because we have added the DIME principle to the cartographic files.

Dobson: I will come to see your output, but the cartographers here are really interested in products. Certainly, there are different types of discussions going on, but some of the theoretical points are not appropriate in this meeting.

Peucker: At least two people at this table are cartographers. Through research they have found that mathematicians and computer scientists have been working in this area maybe longer than cartographers. Cartographic terminology has no more right to be used in this area than mathematical or any other terminology. The term polygon may be used because we are performing mathematical operations on it. As a Canadian I would object to using the term State because I would like to call the area a Province. But, if you suggest that we call it Polygon Virginia, I will accept the term. The terminology doesn't have to be cartographic. At every session we have one guy who says, "Wouldn't you like to use cartographic terms?" Cartographers have changed the terminology, too. Algorithm wasn't algorithm all the time. What is wrong with using other terms?

Dobson: I am not objecting to using other terms but to some types of goals. For instance, you are familiar with my communication with Tobler regarding his paper. He came to the dramatic idea of having a symbol for each different item on a choropleth map. The idea is fine, but it looks like hell. We have 105 county maps and 105 lines. The quorum on stage lacks the balance that exists in the audience.

Chrisman: I don't agree with Peucker. I like 7-class maps; my mother likes 13-class maps. When I bring home fancy output for my mother, I can't bring home a 7-class map.

Dobson: As the Moody Blues say, "There is a question of balance," and balance is what I am looking for.

Peucker: The discussion of Tobler's paper shows a theoretical misunderstanding of the whole issue, and not by Tobler.

Dobson: Tobler suggested that I send my reply to Geographical Analysis.

White (Census Bureau): At the risk of boring the cartographers, I would like to ask Peucker to give some more concrete details about the graph structure that you are coding with surfaces and volumes. I don't understand what you mean by surface-random point.

Peucker: If you put a regular grid on the surface, you get a distribution of the heights, or a height frequency table. This grid gives an average distribution of the heights, but often omits important points, like peaks or passes. Therefore, it is nonrandom with respect to x and y, but random with respect to the surface features. This situation is true for any random x, y distribution of points not directed towards the identification of lines and their special points. We create a data set which approximates a surface with a given error variance and then triangulate the data by assigning pointers to all the neighbors. Usually, we have 6 pointers; but no more than 8. These pointers have label identifications to other surface points, sorted clockwise, so that you can triangulate with any two points. One frequent use of the process is finding triangles and then working with them; another use is crossing an edge and finding the other edge which crosses the traingle again.

Next we extract from that data set a second data set that is restricted to the main ridges and channels of the system. Often we can't link them naturally, and we do so artificially. This structure again makes for a thinner and, therefore, shorter system. The file is created on three levels. First is paging--1,300 points/page; then data sets of 32,000 points, the extent of our numbering, are formed; and finally regions of data are organized.

Moellering (Ohio State Univ.): It is very difficult to say that one data structure is better than any other because the choice of data structure depends on your goals. However, theoretical discussions are not irrelevant. One of the points made yesterday was that automated cartography includes several functions. One is analysis and another is data display. This is what interactive geographical information systems are all about. If you have a CRT system but are interested in a smaller system for research, you can design one to automatically analyze geographical data, sort a cartographic base file, and produce a cartographic display in real-time. But there must be more discussion between the people who are designing geographic information systems and data structures and the people who require cartographic displays and automated cartography.

Schmidt: Your emphasis on goals is a point well taken. I hope no one here got the impression or made the assumption that Chrisman's or Peucker's talks were intended to present the optimum. We are trying to identify a number of alternatives which have been developed as well as some emerging alternatives that we feel have sufficient abilities. We are merely revealing new ideas about how to use cartographic data.

(Unidentified speaker): What is missing is documentation for the optimal use of each method. If someone could formalize this information in one source, it would be very helpful.

Thorpe (Natural Environmental Research Council): We have addressed the same problems discussed yesterday and today regarding hardware and software for the cartographer. The data structure that we developed is a disk-based system. I have a short film concerning the problems of area overlay, automatic area recognition, area mesurement, and point in polygon. We have had this information available for at least a year. What is the big hassle?

Peucker: We also discussed these topics a year ago.

Rockwell (N.J. Dept. of Community Affairs): We not only need to know what is available, but who has it and where it is. I don't know who the cartographers are and who else might be represented at this meeting. A list of the people present and their areas of interest might be helpful.

## Terrain Representation Panel

Thomas K. Peucker, Presiding
Simon Fraser University

Kurt Brassel
State University of New York at Buffalo

James J. Little
Harvard University

Peucker: We have been working on relief representations ranging from contour production to the production of lenticular screens of surfaces that give a three-dimensional view. Here I will discuss only planimetric relief representations, which either produce or simulate relief shading.

In my work on relief shading, I simulated a gray tone, which preserves the structure of the surface if observed closely. The first method (fig. 1) is relief contouring, developed for manual use by Kichiro Tanaka in 1950. (These and other methods have been published in the last International Yearbook of Cartography and in Display and Analysis of Spatial Data by Davis McCullough.) The coutour lines to the southeast are thickened to simulate shadow. An alternative method of shading is to thicken white contours to the northwest and use gray as a base tone. You do not have to simulate gray shading as such, but just suggest a certain structure. In a surface with very few contours you can still see the major relief quite clearly.

Another method of relief representation is the inclined contour (fig. 2). The surface is intersected with inclined planes that are parallel to each other and vertical to the sunlight.

Brassel: Most of my research on relief shading (1971-73) has already been published in journals like The American Cartographer (1973). However, some features have been published in German only. My shading model has two roots: traditional manual hill-shading methods and analytical hill-shading methods. The high graphic quality of traditional manual methods is best demonstrated by a painting of Professor Imhof (slide). (Editor's note: Slides not available for publication.) In order to get ahead in automated cartography we should be guided not only by the technical possibilities of available hardware and software, but also by traditional cartography. A good example of analytical hill-shading methods are those of Yoeli (1965-67), who was the first to shade relief by computer; he illuminated the relief from one fixed position.

A special application of constant-illumination shading is shown in figure 1. Since the light source is vertical (at an angle of 89 degrees), this example truly shows relief according to the formula, "the steeper, the darker." In the 19th century when vertical illumination was favored by some scholars, the light source was often slightly tilted in order to improve graphic effects.

(Slide) Here is the same relief portion illuminated from three different directions: northwest, west, and southwest. With these examples we can

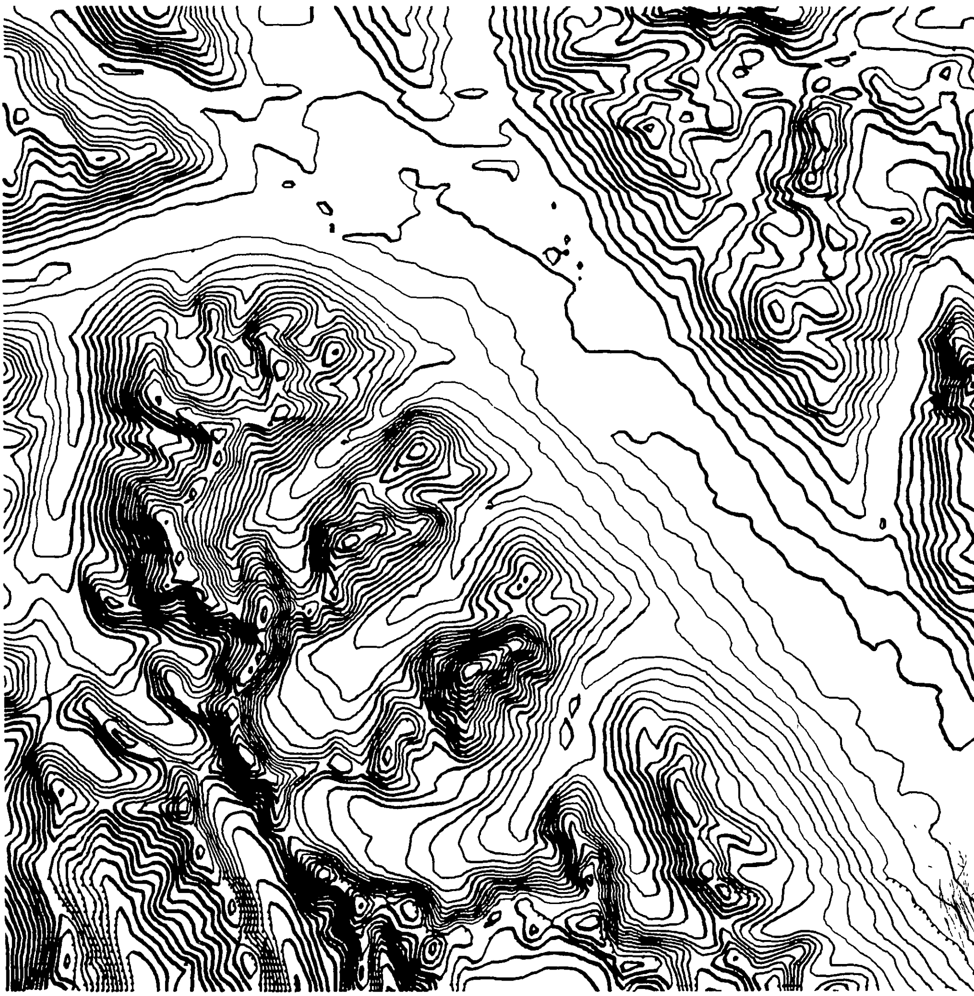


Figure 1
(Peucker)

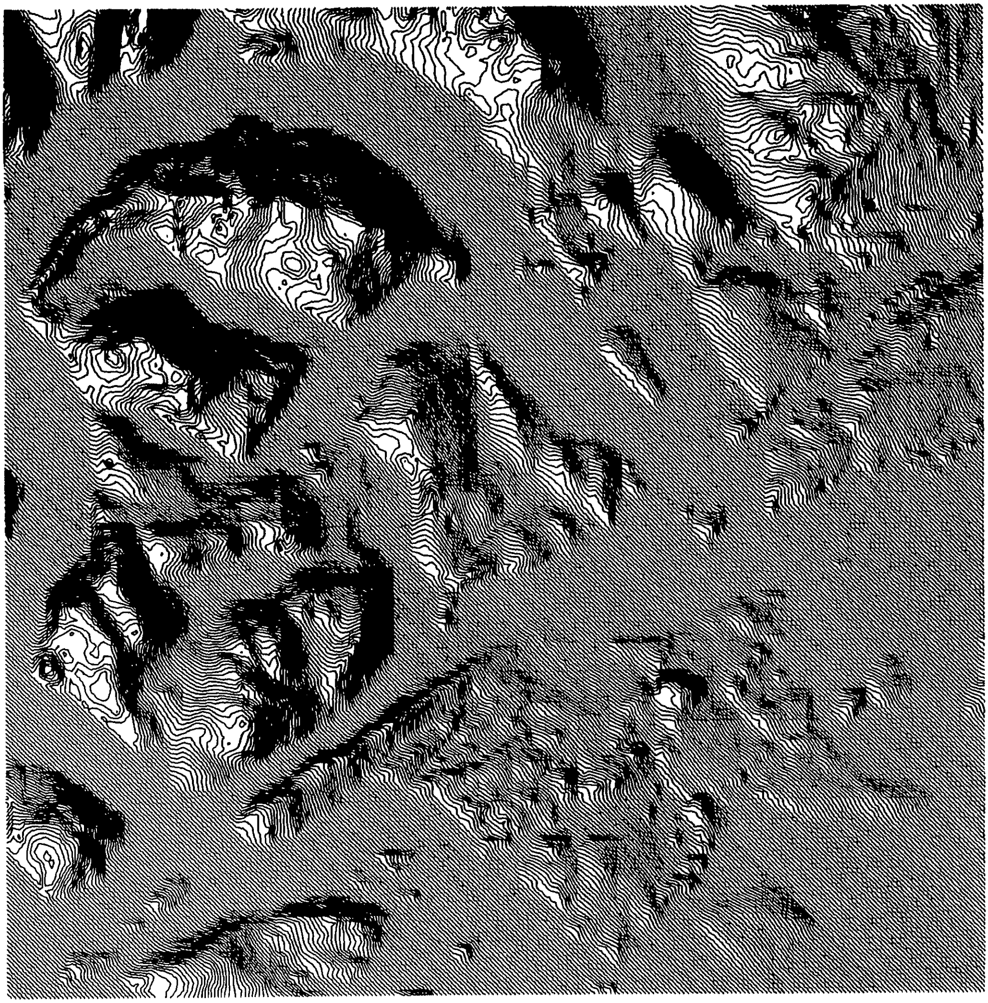


Figure 2
(Peucker)

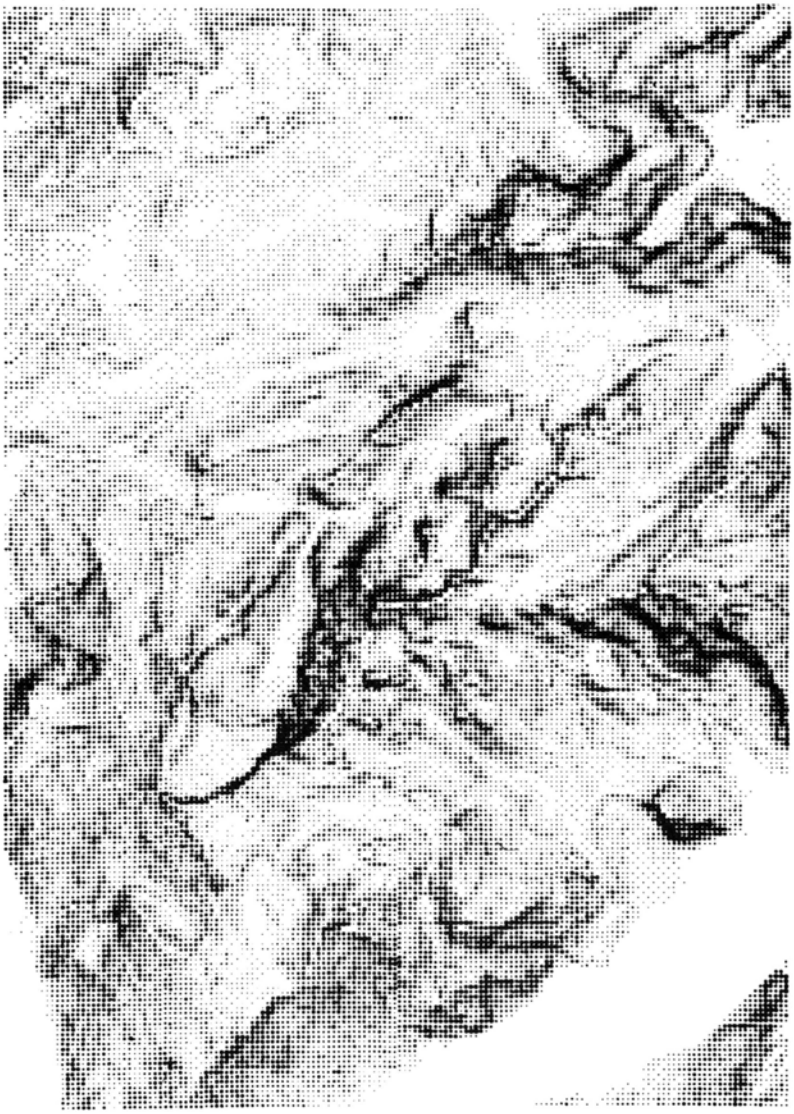


Figure 1

demonstrate that the perception of relief is a function of the direction of illumination. Since the analytical shading model developed by Yoeli does not show the relief realistically, we must search for an extended model. The major difference in my model is an adjustment of the light beam to major land forms. The detailed procedure is described in The American Cartographer (1974). Some ridges are illuminated from southwest and others from northwest (fig. 2); the change in light direction is continuous. Another feature of traditional relief shading used in my model is atmospheric perspective. The amount of gray-tone contrast is increased in high regions and reduced in low regions. (Slide) One shading example is illuminated with atmospheric perspective, the other without.

(Slide) Features other than topographical surfaces may be shaded as well. This slide is a representation of the population density of Zurich, Switzerland. This kind of representation has a lot of problems.

(Slide) This slide shows the line printer for various demonstration displays. With this machine we could change symbols and produce multicolor maps. Modifications in the line printer and the gravure of special symbolism cost about $300. A routine for producing separate layers for different colors allows us to vary the symbolism for different plates and also to turn the screen to avoid moire effects.

The shading model (fig. 3) is a system of algorithms and procedures, grouped in three sections: data, computation, and representation. The actual shading routine is the central procedure in the whole system. It includes the algorithms of Yoeli, the atmospheric perspective algorithms, and the light beam adjustments. The data structures used in the model are old-fashioned--gridded elevation information and a spaghetti file to describe the major ridges and course lines. This second file is compiled by hand: a cartographer interprets the relief, draws edges and river lines, and distinguishes between different categories of lines.

This information is used for light adjustments as well as for a special interpolation of intermediate rows and columns of data points between the existing elevation matrix and can be used to enlarge or to smooth and generalize the relief (fig. 4). Interpolation keeps ridges sharp and smoothes surface portions, thus retaining the characteristics of the original digital terrain model. In some tests, samples of the original data set (1/4, 1/16, 1/64 of all data points) were taken, and the surface was regenerated by interpolation. (Slide) Notice the progressive generalization and deterioration of the relief as the sample size decreases.

Peucker: How can we develop a relief-shading system that will do the whole job in a production shop? There are several problems involved. Since the procedure is still relatively slow, we produced a linear approximation that reduced the cost per point to about 3 percent of what it previously was. We usually have two basic scales for relief-shading--large scales of 1:25,000 or 1:50,000 and small scales of 1:3,000,000. The data problems are very different. With large scales we have data for any grid density that we want. With small scales we do not have such data, but we do have more than the surface structure (e.g. the river and ridge system). We have more indications of the local relief variation than absolute heights.

The problem therefore is to create relative differences. With the

Figure 2.--Automated relief shading. Light source is locally adjusted to land forms.

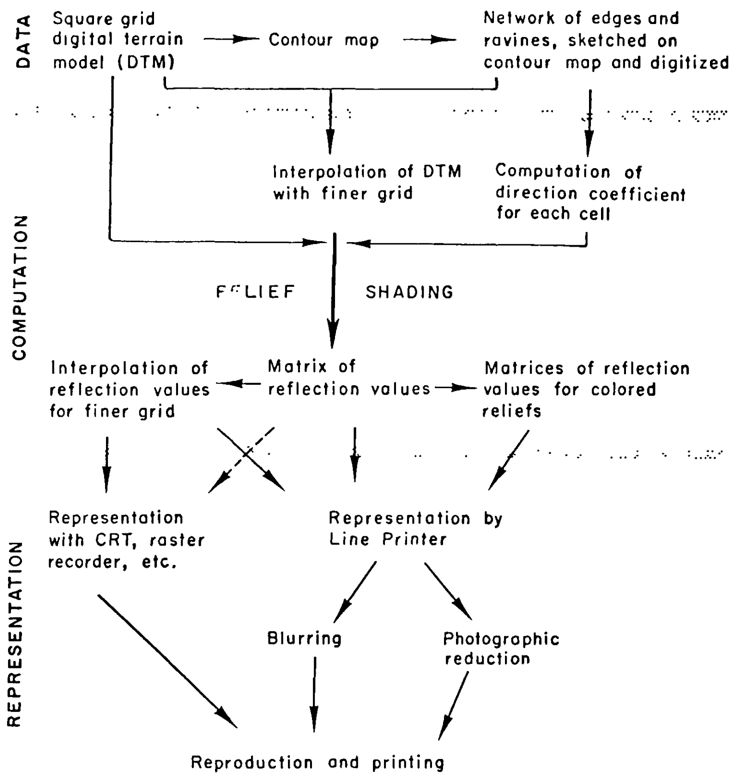



Figure 3.--The basic phases in the production of a computer shaded map. (Courtesy of The American Cartographer)

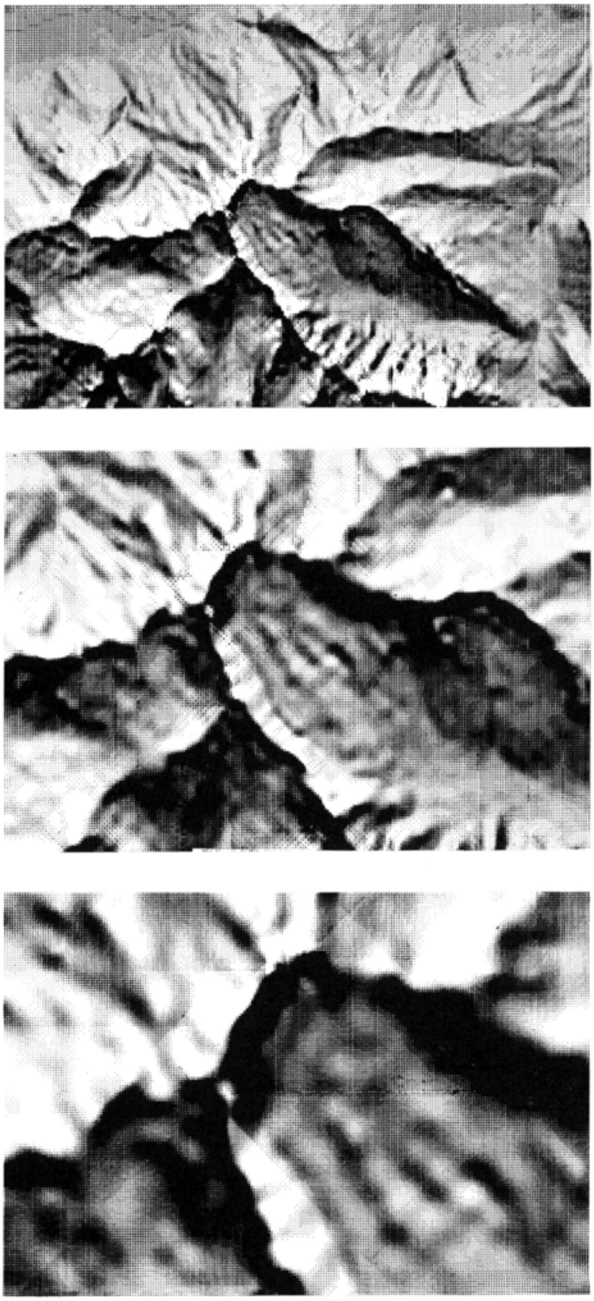


Figure 4.--Interpolation of intermediate rows and columns of data points and subsequent shading with the HILLSHAD program.

whole system on our data structure, we could produce a shading record for each slope and use that record whenever we have to use a map projection at that scale.

Little: The visual methods of automated terrain representation have been adapted to available data and current technology. Automation has stimulated the development of several new methods of display as well as sharpened older methods. Contour maps, long the prevailing style of display, are now produced automatically from various digital terrain models (DTM). Several methods, which were tedious if not impossible by hand, have been programed. Analytical hill-shading (Yoeli) and Swiss relief shading have been handled in programs by Peucker and Brassel, for example. The first may well have been impossible without the computer's aid; the latter, time-consuming. I will discuss a third method, block diagrams or surface relief modeling (fig. 1). Since relief modeling implicitly involves hidden line removal, an expensive process, its use has been customarily restricted to final output of collected data (mostly for display) and to mapping of terrain data. Maps are customarily expected to be printable products. Today the easy availability of terrain data for large regions and the use of graphic terminals (cathode ray tubes, either storage or refresh) offers the possibility of interactive use of relief maps. Since terrain representation by relief modeling provides a simple global view of the shape and variability of the surface, this method can be used not only for display but also for investigation of the data. Relief models can be interpreted easily by casual users as well as trained geographers.

To produce surface maps quickly in an interactive environment, the Laboratory for Computer Graphics and Spatial Analysis, Harvard University, has developed the program ASPEX. Gridded data storage remains the most popular storage method for surface data although such methods as local polynomial surface patches and triangular networks are presently in use. However, because of the availability of grids and the possibility of interpolation from other forms, ASPEX deals with grids stored in matrix format. Currently many block-diagram programs are available--SYMVU of the Laboratory of Computer Graphics, Calcomp's, Douglas's VIEWBLOK, and many others. Most are constrained by the size of the grid matrix of data, up to a typical maximum of 130 by 130 as in SYMVU. Many data bases today are much larger. Thus to produce a relief map, cumbersome techniques were used to split the data into manageable sections, requiring cutting and splicing to assemble the finished product. Against this constraint, ASPEX adopts a strategy which partitions the grid as it is input, spooling data onto secondary storage and handling sections within the core. In this way the amount of data to be modeled can be limited only by the size allotted to pointers marking the sections. Since the size of the sections can be altered at compilation time, the total size of the program can be tailored to suit the time/space tradeoffs at the installation.

Within an interactive situation, complete graphic representation often must be balanced against speed and storage constraints. For storage tubes, like a Tektronix graphics terminal, the drawing time is directly proportional to the number of line segments in the image. For refresh tubes, the storage required is also proportional to the number of vectors. For a block diagram of a digital terrain model in a 100 by 100 grid, the number of visible line segments can be up to 10,000. On a slow speed line the transmission time can easily be 15 to 20 min. To solve this logjam, ASPEX has a generalization feature using a routine

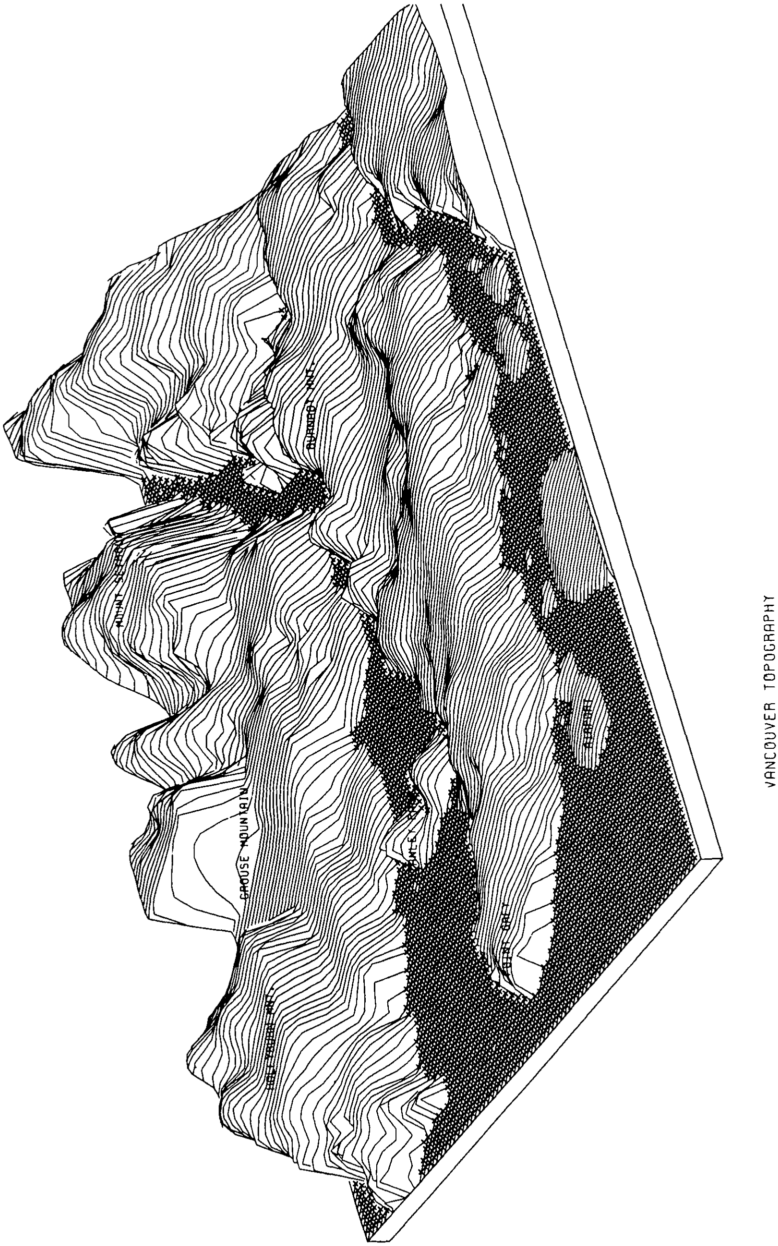



Figure 1

written by Douglas (1973). The points in relief that deviate less than a user-specified minimum from the general trend of the line are removed. Figure 2 shows an ungeneralized plot. At the resolution of a typical CRT, or 0.01 in, across a drawing approximately 7 by 9 in, generalization can cut the plotting time in half and thus reduce the storage requirements (fig. 3). Using a larger minimum, 0.02 in, reduces the drawing time still further to 35 percent of the original (fig. 4). With a minimum of 0.03 in, the detail is again reduced (fig. 5). This process has a practical limit at which the major relief is altered by generalization, but at lower levels the process still reveals its usefulness.

Similarly the plotting time can be reduced by dropping every second or third relief line within the image. By combining this technique with line generalization, the image buildup time can be considerably reduced without much information loss. A map in which every third line has been skipped (fig. 6) takes two-thirds as long to create as a full image (fig. 5), and when every second has been removed (fig. 7), half as long. Not only is this technique time-efficient, but elimination of some of the lines often clarifies the global trends of the surface and eases identification of the major relief features. The relief components of high frequency can essentially be eliminated, removing what is often a noise component. Whether the smaller relief, however distinguishing, is in fact significant is a decision for the analyst using the program, not for the program itself. We have merely opened the option to examine data in this manner.

Besides speeding up the drawing process for interaction, ASPEX implements virtual image methods and windowing and clipping techniques prevalent in many interactive applications. Explanation of these methods can be found in Principles of Interactive Computer Graphics by Neumann and Sproull (1973). Most block diagram programs, such as SYMVU, restrict the viewer to a vantage point outside the surface for scanning the entire surface. In ASPEX the vantage point can be placed anywhere above or outside the surface, and the central point of the image can be anywhere. Using this option one can zoom in on portions of the data of special interest and produce a map showing the relief at larger scale and unobscured by surrounding relief. In a closeup view, parts of the image must necessarily extend outside the range of the tube plotting area. We must clip these parts as they leave or the lines will wrap around the scope, entering on the other side. The windowing routines in ASPEX handle this difficulty without significant expense.

In figures 8 through 11 we zoom in on a model of the relief of the conterminous United States, from the Northeast to Denver. The sequence gives a vivid impression of the changing landforms across the country, adding a new dimension in display techniques. The generalization, zooming, and windowing options are applicable to maps on a pen plotter and in a batch environment.

The sum of these techniques in ASPEX provides many of the features of interactive display for block diagrams. Generally these methods are making an impact in geographic data manipulation and display, most significantly in the manipulation of regional data bases for social, economic, and legal land-use planning. The combination of several sources of data where the regions overlap (e.g. housing data with job statistics) is currently a feature of many regional data base systems, and we expect that this combination will also be true with DTM's and

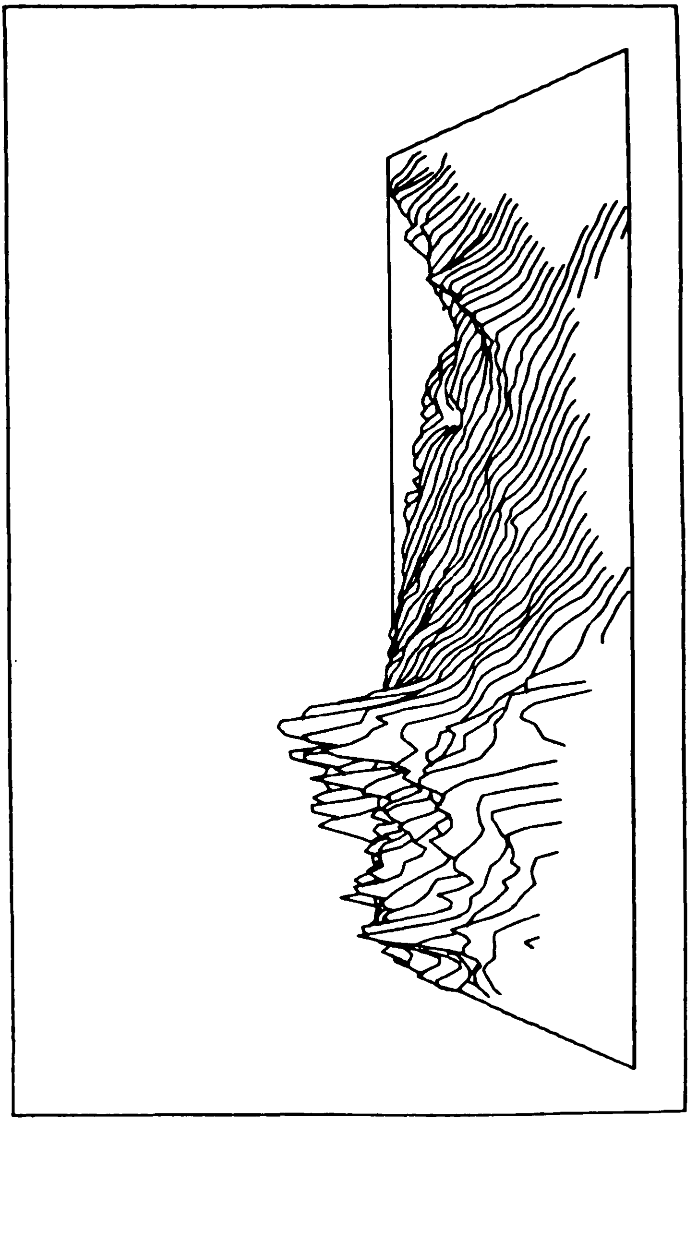


Figure 2

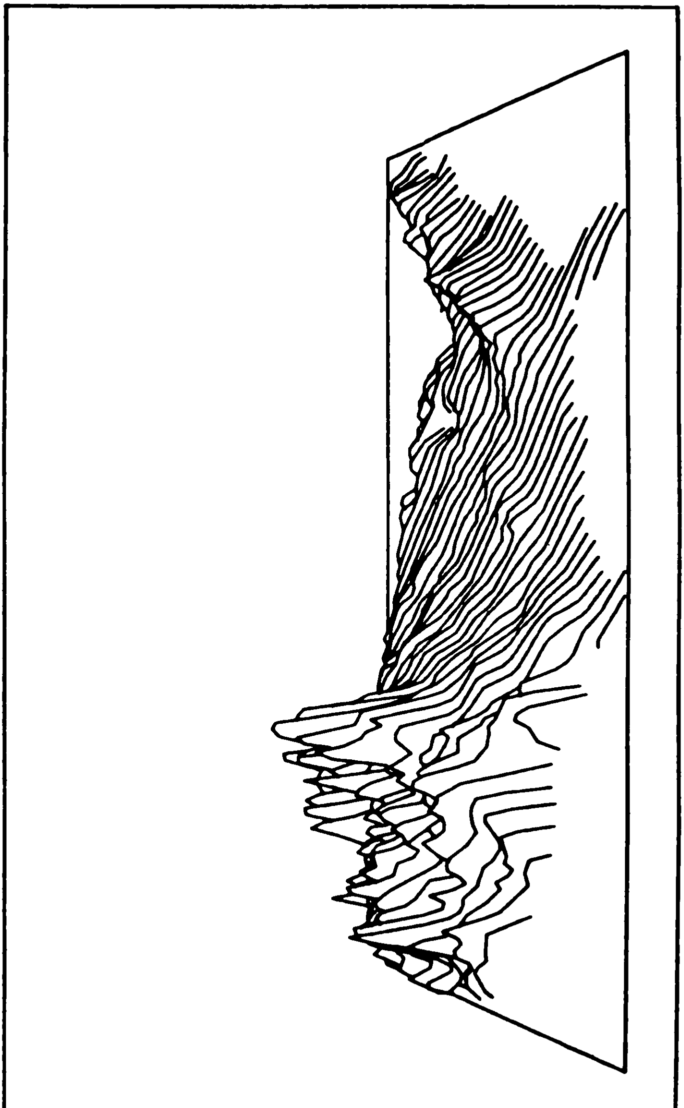


Figure 3

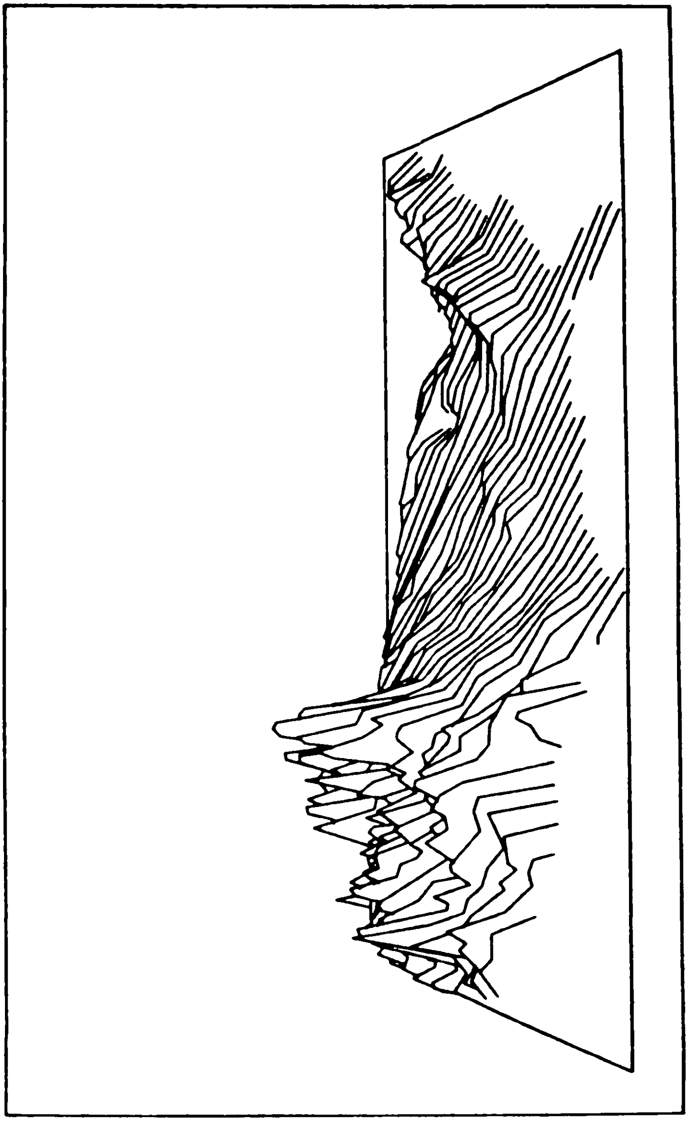


Figure 4

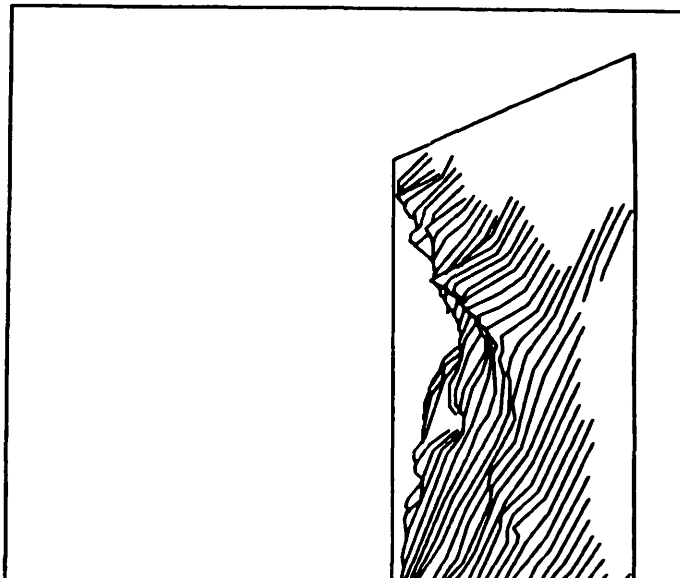


Figure 5

Figure 6

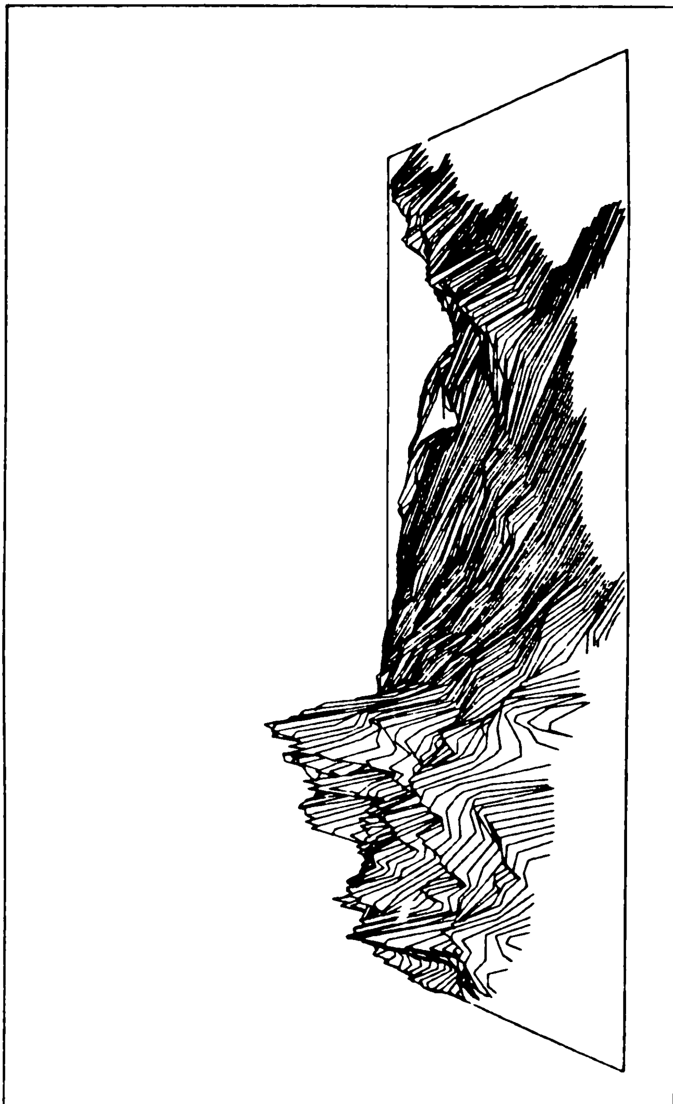


Figure 7

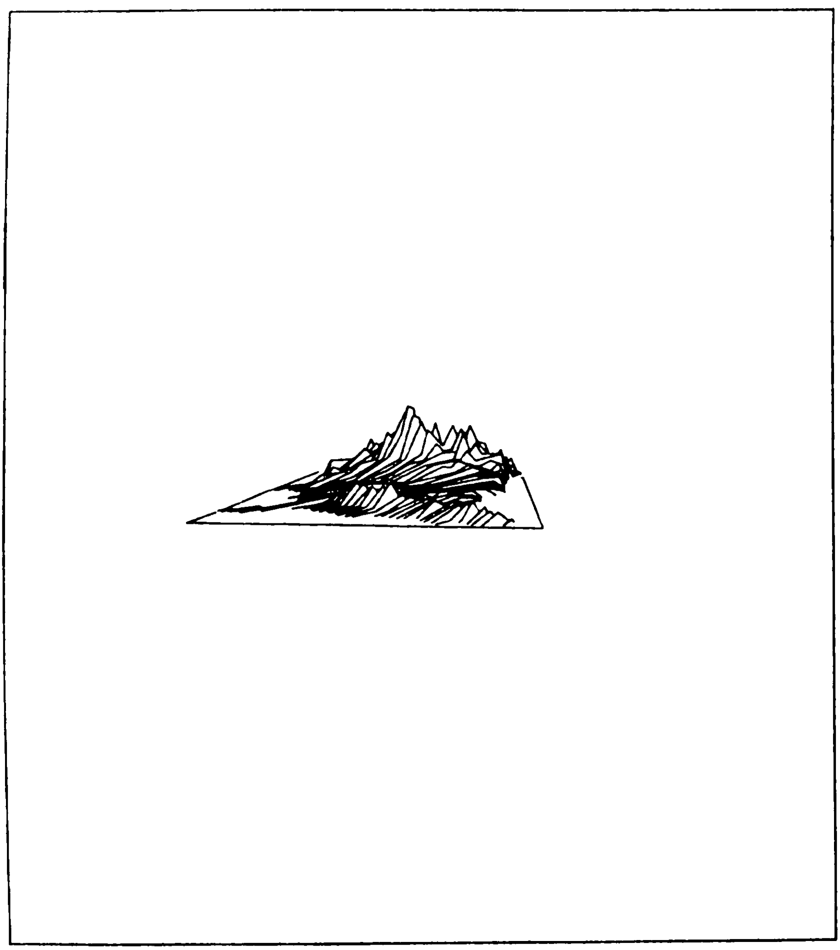


Figure 8

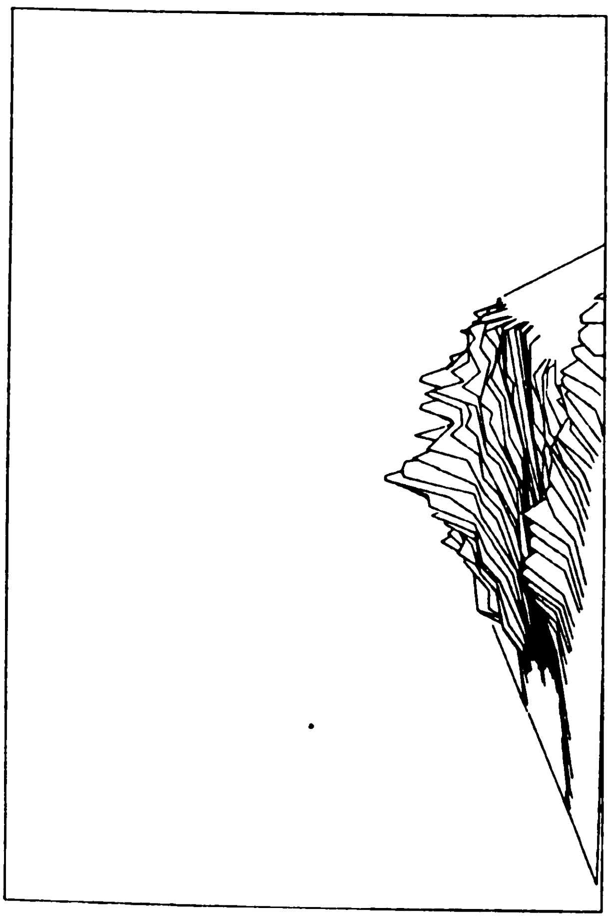


Figure 9

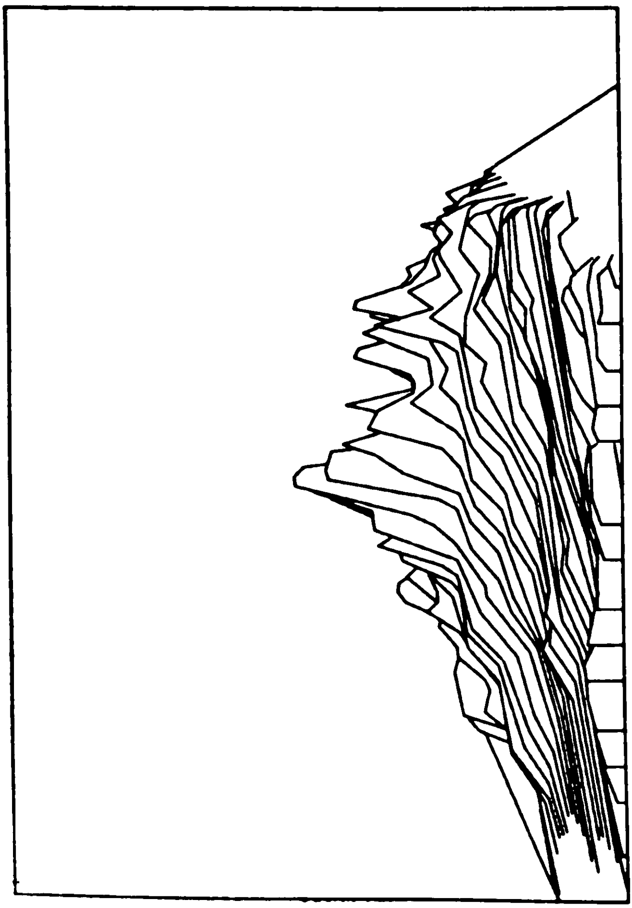


Figure 10

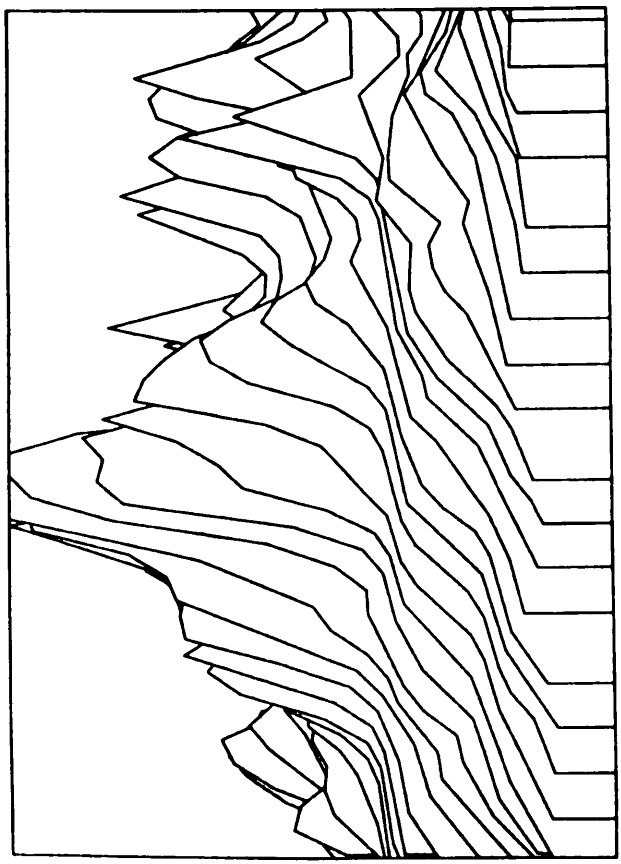


Figure 11

regional data. These overlays can be displayed in several fashions, including color separations of the varying data groups. Figure 12 shows the forestation of Dentes de Morcles, Switzerland, produced by plotting the forested and unforested land groups separately and then combining them in the printing process.

Further development envisioned for ASPEX involves plotting cultural features as lines on the surface and drawing polygonal data, such as land-use types, on the relief and overlay of contour lines. Both developments should significantly enhance the readability of these maps. By setting surface modeling in an interactive system and enhancing the possibilities of thematic mapping over DTM's, we hope to increase the geographer's understanding.

Rockwell (New Jersey Dept. of Community Affairs): How much core does it take to operate ASPEX?

Little: We were working on a Digital Equipment Corp. computer, PDP-10. It takes 24 k right now, but we have an overlay that goes down to about 16 k. You can make it as small as you want.

Rockwell: Could you run ASPEX on a PDP-11 or a large -8?

Little: Certainly.

Broome (Census Bureau): I noticed that you were talking about how long it took to plot data on the tube. Is this time a function of computation time or transmission time?

Little: Transmission time.

Broome: What bar were you operating at?

Little: 300 bars, which is typical.

Rhind (Univ. of Durham): For many users of big machines in an interactive system, the time that you wait for the data has increasingly less to do with the central processing time or even the transmission time. Virtual memory machines are often working until the page comes through. You can't do anything about this situation except organize the data structure in a way that minimizes the number of pages needed.

Little: On a virtual memory machine you should act as if you were on a PDP-8.

Broome: Virtual memory machines are unpredictable with our programs. This strategy allows us to reduce the size and work as if we were in a few pages.

Rhind: I do wish that you would stop calling that thing the Tanaka Method. It was used by the British Army in the 1840's.

Peucker: The method is attributed to Tanaka because he was the first to formalize it mathematically. Incidentally, about the transmission time, 3 years ago I was happy to have a turnaround time of half a day. Now people are nervous if they have to wait a few seconds.

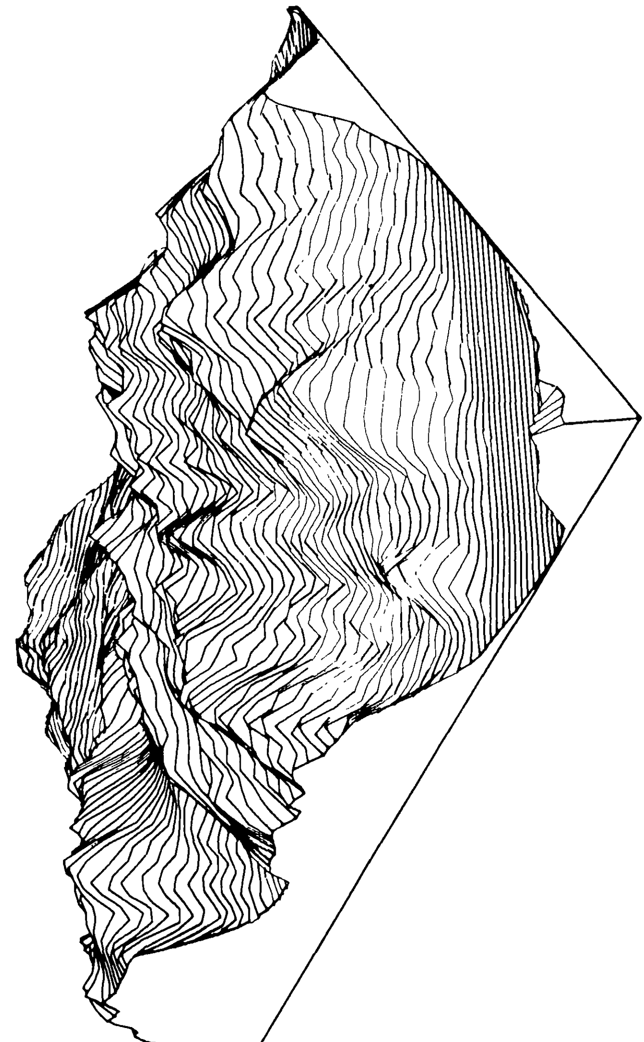


Figure 12

# Cartographic Manipulation Panel

Ronald Bolton, Presiding
National Ocean Survey

Nicholas Chrisman
Harvard University

Michael McCullagh
University of Nottingham, U.K.

David W. Rhind
University of Durham

F. Robert Niedermair
National Ocean Survey

P. Frederick Stepler
IBM Corporation

Bolton: Since I am a specialist in data manipulation, you would expect me to say that cartographic manipulation proceses are so far advanced that we need more and better hardware. But right now we have more sophisticated hardware than we can use. We have computers that stay operational 98 percent of the time, cathode ray tubes that are almost 100 percent reliable, plotters that can run 1 to 2 consecutive days without any significant problems, and digitizers that can reliably digitize 1 to 2 mil day after day. We have the hardware to do almost any manipulation of data, but we are not keeping up with the hardware. One of our problems could be an asset: the diversity of interests.

A key problem in manipulating digitized data is inaccuracy in the maps to be digitized. Much of the data base of World Data Bank I, used by by the CAM system, had to be revised. The existing maps were distorted and had compilation errors. In many cases you will have to recompile, go to photogrammetric sources, or make corrections on the sheets to be digitized.

Another problem is organizing the program requirements for the programer. You cannot just write a program by studying someone's operations for a few hours. Writing manipulation programs requires cartographic and mathematical knowledge. Most systems grow; they are not adequately defined in the beginning. In requirements development it is essential that purpose and product be accurately defined. Then a programer, mathematician, cartographer, and a data base specialist working together can help you. The resources needed for manipulation of cartographic data are not usually contained within a single orgranization. Probably no one person in the audience can do everything necessary to complete a cartographic manipulation process.

Before manipulation begins, materials must also be considered. We study everything--Mylar, scribecoat, deformations of paper, output devices, plotters, CRT's, and COM devices. We just see if these devices can actually produce the desired product. Many people do not test their equipment, and they fail.

We have also failed to keep up with hardware because we have not gathered together the resources in the average installation before automating. I have just spoken of what skills are needed. What do you need in dollars and manpower? Even a small system is expensive. For example, the Tektronix tube and interactive plotter on display represent 25-man years, and this system is small. When considering the cost of automated cartography, you must also think of the future: how many people and how much money will be needed to maintain the equipment? In successful systems a great percentage of the initial investment is used to keep manpower in-house or on contract for the first few years in order to maintain and update the system. Maintenance can account for 60 percent of the manpower used to develop the system.

Cost-effectiveness is also an important consideration in automated cartography. Manpower can be exchanged for machines at an even level. I used a modified version of the spaghetti file to generate world shorelines and saved a lot of money. Instead of spending 5 or 6 mo making the map, we spent $120 for computer time. In the Navy alone, we used that data bank enough to pay for its cost. Though to some people it might be a spaghetti data bank, to me it was cost-effective. But there never is a good reason for automating something if you don't save money, if you don't increase speed, or if you don't acquire new capability. Many people, in striving for 100 percent accuracy, spend more money than they would spend getting 98 percent with the automated system and then finishing the job by hand.

My final point is that our data manipulations are not easy enough for the average cartogarpher to use. As a result you may find that your manipulation system isn't used. While we think that is is easy to type in 15 commands on a CRT command program, this task is hard for a technician who has been working on paper. We must combine human engineering with our software and hardware manipulations.

Although I have talked about some of our failures, we are advancing. As long as we keep our feet on the ground, define our requirements, and get the people in our organizations to do the job, automation will be a success.

Chrisman: We spend most of our time processing coordinate points. Therefore, the quickest, cheapest way of reducing the cost of operating the system is to find a way to reduce the number of coordinate points processed and still get the same result. Every existing data base is good down to a certain accuracy, but it is not always used at that level. We have done some work at the Harvard lab with a point reduction algorithm developed by Douglas and Peucker at Vancouver (also independently discovered by someone else). This algorithm was explained in The Canadian Cartographer (1972).

There is some garbage in a file like the New England county DIME file, which has 2163 coordinate points. Using a detailed filter based on the plotter increment of this device, we can get the same picture reduced from 2163 points to 1700 points, a substantial reduction. The internal points of the chain can be dropped out at will because with a topological chain the nodes will remain. We can reduce to 962 points and still get a fairly good representation, although it will begin to look "liney." We can go down further and almost get a characterization, which is still fairly good. If you are using SYMAP, there is no problem.

For every output device there will be an effective level of generalization. That level will allow you to cut costs either substantially or inconsequentially depending on your requirements for accuracy. Consider for example the coarsest piece of World Data Bank II--Australia. In this first picture Australia is plotted at a somewhat smaller scale than it is capable of being plotted at (although not an abnormal plotting scale). (Editor's note: Pictures not available for publication.) It has 18,218 points, a lot to a plotting routine. Plotting Australia at this scale would not be feasible if we were not working on an off-line plotter. The next picture has 1,000 points--a reduction by a factor of 18. There is no visible difference because I used the plotter increment as my step size. This one interaction with the data structure can produce terrific reductions in cost. We should not be dealing in relative coordinates, which require us to keep all the points, but in absolute coordinates because the amount of processing, not the external storage, is the real problem. Using absolute coordinates can really reduce the processing requirements.

McCullagh: I want to consider three main problems with data manipulation. But first, however, I want to say that I agree that, for production, cost effectiveness is a good yardstick. When you are simply automating a present cartographic technique, cost effectiveness can be calculated. As soon as you introduce new methods, however, cost effectiveness is impossible to measure because you can't do much by hand. For example, the color, multivariable mapping and the various possible relief representations are almost impssible to do by hand. You can't expect them to be cost effective because you have no way of determining that effectiveness.

The first problem has to do with access to data. Most people are very worried about the difficulties of data storage and representation of that data set. However, a long-neglected aspect is access to core data. If you have no effective means of directly accessing this data, you will waste valuable CPU time just trying to find what you need. For instance, if you happen to be storing data matrices and you want particular statistics--items, values, or shapes--you have to go through the matrix sequentially, usually using FORTRAN to make everything compatible. A formula translation language doesn't seem very appropriate to cartographic needs because its operations are based on engineering concepts and designs rather than on geographical categories. Working with image processing at the University of Maryland, Foltz and Rosenfeld have tried to develop products like the PACKS language to overcome these accessing problems. The orientated language of such a system allows a user to discover features and boundaries with little difficulty. However, these orientated languages are probably not too fast. Maybe what we ought to be considering as well as cartographic storage and representation is the development of a high-quality language to represent cartographic locational problems.

The second problem is storing large amounts of data. Word packing can economize on the core store but only at the sacrifice of the accuracy of the data. However, in many cases you may need to store a number to 5- or 6-digit precision, and in such cases you can't make any great savings in store by word packing. Various people, again at the University of Maryland, have suggested "bit-plane encoding," a parallel processing capability for either software or hardware. The PACKS language is a software-oriented, parallel processing language that enables you to do operations on different bit planes; a bit plane is simply a binary map of part of the data set. Without even using a special language maybe this approach could speed up cartographic data operations. In many cases you can't store all the data anyway, and you must use row-by-row, column-by-column, or tree-by-tree structure. Then speed depends not so much on the core access system as on the back-up structure. Random-access disk has been around for a long time, and everybody tends to use it at great cost. Even with exchangeable disk packs in many machines, algorithm cost is based on the number of transfers performed. For a research organization this system can quickly become prohibitively expensive.

The third point involves working with a data set. It is not always possible to tell whether your data are clean. For example, in Kansas there is an API file with a tremendous amount of valuable well-log data, but the errors in this file are many. They were discovered during the development of a graphics package called Surface II by the Kansas Geological Survey. The errors weren't noticeable until we started plotting block diagrams or contour maps and suddenly discovered elevation discrepancies of about 1,000 ft higher at one point than at another. This example shows how graphics could be used in an apparently nongraphic field. A well-log system is not usually thought of in a graphic form, but you could discover errors using image processing techniques on these data sets. The error checking sections of the Kansas oil exploration project have produced significant improvements in the API well-log system.

Rhind: Before I discuss generalization, I will follow my U.K. colleague's lead and speak to the chairman because another critical aspect of automation has been omitted--we must think of automation for the future as well as the present. Of course, the manpower situation is critical. Already in some parts of the U.K. we have problems getting draftsmen. On the basis of methods suggested earlier, I have just worked out the way to save colossal, indeed infinite, amounts of money: draw as many maps as possible, the faster the better. The fact that I wouldn't have drawn them before is perhaps irrelevant.

Recently a number of papers have been published on generalization in automated cartography, the most recent of these by Peucker and Douglas in The Canadian Cartographer and by Stewart in The Cartographica Monograph. I don't mean to imply that such recent papers are the best, but that these papers are important and easily obtained. The most important characteristic of generalization in an automated environment is that it permits you to rely on the graphic depiction. This reliance is possible because the rules must be explicit in automation, whereas in manual cartography there often aren't many written rules at all. Even where rules do exist, they are variously interpreted by the individual cartographer.

Even more important though, we can't sensibly involve ourselves in generalization by machine until we understand what we can actually see on the maps. We can go through elegant line simplification routines, but this process may be quite unnecessary; instead, it may be completely satisfactory and much simpler to throw away every second point, or every third point, or *n* points every second. Simpler algorithms are adequate if we can't see any differences between the final products. The recent work in cartographic perception is improving, but we still know very little about what we can actually distinguish on map forms.

Most talks proceed from a definition--I am following the reverse process. Another problem is defining generalization. I don't refer only to line sinosity reduction, the most normal application, but to ways of thinning the available data to reduce the plotting time. When you have 6 different areas and wish to map them as 3, the problem is not only in the representation but also in the data. We have to consider the data characteristics as well as the cartographics.

Let me conclude with two points about line smoothing as a sub-category of generalization. First, there are many different algorithms for line unwinding. Making some assumptions, all algorithms are equally correct unless we have some theory of what is desirable. We must have something better than the present idiosyncratic intuition before we can get very far with automated generalization--unless we define generalization merely as money-saving. Second, line-unwinding routines so far have performed sequential operations. As a result, some algorithms have neatly produced crossing lines. Very few algorithms for line unwinding treat the whole map or even part of it as a map, except for some work by Hans Gottschalk.

Generalization capabilities--when we actually find out what they should be--are an important constituent of a geographic or geometric processing language. Indeed some computer languages already enable us to talk of graphic elements. While we still have a long way to go, generalization should be in such a language.

Niedermair: I'm here to talk with you about a system originally designed to support FAA's National Airspace System. Perhaps the system is rather mundane, compared to some of the other systems that we've talked about. It only produces a product every 28 days, but it is a working system. The system produced a book intended to maintain over 20 data bases at air-traffic control centers throughout the U.S. Because picking the latitudes and longitudes of airways off the charts proved tedious and inaccurate, we were asked to produce a book of these airways to within 0.1 sec. While producing this book, we got requests for data other than the book--chart plots, magnetic tapes, and air route change lists. Among the magnetic tapes produced by the system is a Linetron tape, an automatic typeset tape. The controls for the Linetron, such as the typeset, the font, and the centering of the columns, are put on the tape, and the tape is sent to the Government Printing Office for printing. I have the book here if anyone is interested in the printing quality of this system.

At first we kept the product data separate from the base or fixed data so that the fixed data would not become product oriented. One major advantage of this approach was that a fix (a latitude and longitude in this particular book) was only in the master data set once and could be used in as many products as need be. Another advantage was that the product information could be kept separate, thereby enabling us to change certain products without changing the master data set. When we received requests for products other than the book, separation of product data and fixed data proved especially advantageous.

To identify the charts affected by a particular change in the data base, we have implemented a polygon search routine that determines where a part of the polygon falls within each quadrant of the Cartesian coordinate system, the origin of which is at the search fix. The test runs very quickly--we can tell by testing as few as two sides whether the change is internal or external to the polygon. The system identifies the affected charts by using a cross reference by geographic area between two charts. The geographic area is an arbitrary consideration. For example, 1-degree squared is an entry in the data base. The address of the entry, its latitude and longitude, is in the lower right corner of the grid square. There is an entry for each section of the geographic area covered by the data base.

Each entry in the cross reference has a pointer to a chart record which contains such information as corner postions of the chart and the type of data on the chart. If a fix has a change, longitude is concatenated to the latitude at the fix and used as an entry point to the cross reference. For the latitude and longitude the pointers to the chart record are picked up one at a time. From the chart records a preliminary determination is made if the data are charted at all. If the data are supposed to be on the chart, the corner coordinates of the chart are applied to the polygon search, and the polygon search determines whether the fix is actually within the chart. In general, the software has made a gross determination of the area of the fix and applies to the polygon search only the particular charts that fall or overlap that geographic grid square. With this system we do not test charts in Maine for a fix change in southern California. Thus this search technique is very quick and very efficient.

The cartographer can use the search himself by using the symbolic address of the record in the chart data set. This process greatly reduces the amount of input needed to compile or recompile a new chart. He simply puts in one parameter. The rest of the parameters are taken from the chart record, and the search is applied to the data base. If we get a special request chart, the parameters to the search can be put into the data base by the cartographer. In the system we use a free-form, key-word parameter control. We found early that by using positional parameters to control the system, with a certain punch in a particular column, we had many wrong runs. Using a batch system, our turnaround wasn't too good. Sometimes we had to wait as much as 24 hr to get another run back. I then decided to use a key-word parameter--the system recognizes the word and sets up the controls itself.

Using some slides I will quickly go over the basic data structure of the system. (Editor's note: Slides not available for publication.)

(Slide) The master data set is a type of index sequential file. These dotted lines representing links are the auxiliary set, a strict direct access file on a mass storage device. The master data set is entered using symbolic parameters in the index sequential mode. The auxiliary storage is used in stacking, chaining, and indexing. For instance, an airway gets longer, more area is needed on the disk, and cells in the auxiliary storage are linked together to accommodate the extra area. We wrote the change in a modular fashion using high-level languages for easy transferability and maintenance. The two languages used are COBOL and FORTRAN. The drivers are written in COBOL, the computation subroutines and some of the search routines are written in FORTRAN, and the rest of the search routines are written in COBOL.

(Slide) This plot is a Boston area Air Traffic Control Center (ARTCC) region done by this system. We had a special request from the Boston ARTCC area to plot NAVAIDS, the circles and air routes which are the lines and the boundary of the ARTCC. The boundaries don't show. The plot is rather crude, but as Bolton said, to travel that last mile can cost double what it cost you to go 98 percent of the way. With this plot we're 98 percent there. The cartographer will touch it up, but the software has put the points and the graticule down accurately.

Stepler: The fourth version of CAM is now available. The documentation came off the press Monday. Those of you who attended the CAM workshop, have already received copies. There are some new features in this version: a polyconic projection, UTM grids and ticks, latitude and longitude ticks, legend block blackout, and 12 new line symbols including 4 varieties of dash lines, 6 varieties of railroads, and canal and reef symbols. These features are independent of the plotter.

In our system and in both World Data Bank I and II we decided to use output generalization. (Slide) The first slide shows generalization at various scales. (Editor's note: Slides not available for publication.) We decided to use output generalizations because changing projections distorts the output. A line on one projection takes a different shape on a different projection. Also our scheme eliminates commands to the plotter. (All the projections were produced on the Gerber flatbed plotter.)

(Slide) The algorithm is very simple. We just compare the point of interest with the previous point plotted, and if the delta-x and -y are less than some input value of 0.2, it is not plotted. I have several examples of data from World Data Bank II plotted at the same scale but with different dropout factors. In this example we had a dropout factor of 0.01 in.

(Slide) This slide shows the same area but with a dropout factor of 0.02 in--there is little change. You begin to see the change with the next dropout of 0.04 in. The straight lines lengthen and begin to lose their character.

(Slide) In this last example, with a 0.06-in dropout, the lines really begin to lose character. For most of the work we use the 0.01-in dropout and find it quite satisfactory.

Finally I want to discuss the data structure for World Data Bank II Since we knew that we would have a number of points in the Bank, we needed a different structure than that of Data Bank I. As a result, we came up with two data sets for each feature. One data set is simply a table data set with one record for each line. That record contains a line identifier, the rank value of the line used to determine the map scale on which the line should be plotted, the number of points in the line, and four values for the latitude-longitude limits for the line which serve to window it. We also have a pointer to another data base giving the longitude-latitude values for that line start. The second data base includes simply the latitudes and longitudes set up by about 100 values in each record, and again, retrieval is rather simple.

(Slide) We read a record from the table data set and compare the latitude-longitude limits against the map that is being generated. If the line is outside the limits of the map, it is not read or transformed. Next, we examine the line identifier. The user has the option of selecting all the line identifiers for a feature, selecting a range of line identifiers, or just pulling out one line. Here the line identifiers are checked. The user can also select by rank, either all ranks or individual ranks.

Robe (Central Intelligence Agency): In Bolton's introduction he said that World Data Bank I was compiled, but that is not exactly so--it was taken primarily from one source. World Data Bank II, however, was compiled from numerous sources.

Moritz (PRC Information Sciences Co.): Everyone here should consider the relative cost of hardware and software. When considering the cost of software, it is misleading to consider just the cost of running an item through a machine or just the cost of developing the program. Many different variables should be considered to estimate the cost of software. We must also recognize the fantastic impact of hardware on the cost--the cost to rent IBM, CDC, or UNIVAC equipment, to keep a disk file, and to use the equipment. On the other hand, a minicomputer will cost from $4,000 for stripped-down models to $120,000 for full-blown systems with hundreds of megawords of storage. In the latter case, once the purchase has been made, the operation costs are largely labor. In some laboratories the same people are doing the programing and the research and running the machine.

Chrisman: You can move software from place to place, but hardware is difficult to move. Software people can exchange ideas and give the tools to everybody. The hardware people, who have a physical device, can't be so generous.

Cartographic Symbology Panel

Clyde G. Johnson, Presiding
Soil Conservation Service

Allen V. Hershey
U.S. Naval Laboratory

Aubrey L. LeBlanc
Ministry of Transportation and
Communication (Ontario)

Johnson: When I was asked to lead this panel discussion on cartographic symbology, I thought of the symbol set that we are currently using in the Soil Conservation Service (SCS) and believed that this was going to be a very narrow topic. Then I looked up the definition of cartographic symbol: "a letter, character, or other graphic device representing some feature, quality, or characteristic on a map or chart." This took the very narrow topic and made it very wide.

My area of interest is the production of base, soil, and topographic maps for SCS technicians' use. These maps include boundaries, roads, railroads, drainage, names, and, for soil maps, lines delineating soil boundaries. This week I have become aware of another type of map that uses symbology. Such a map might be classified as a statistical map, for example, maps that show population density, where certain crops are grown, production, slope, and many other items. I had asked someone to be on the panel to discuss this type of symbology but he was unable to attend so I will encourage you to comment on symbology for statistical mapping during the discussion period.

Hershey: As a mathematical physicist, I prepare equations which are published in laboratory reports. In order that my equations might be printed in an elegant format, I have had to develop my own typographic system. Specifications for the system have dictated that it should provide good quality, be completely versatile, and be fully automatic. The primary function of the system is printing mathematical reports, while a secondary function of the system is plotting cartographic material--not only maps but also graphs and diagrams. The system makes it possible to mix textual and graphical material on the same page.

The structure of my topographic system is controlled by limitations on the type of equipment which is available to me in my laboratory. We do not have automatic digitizers or character readers. We do have key punches, a computer, a mechanical plotter, and a cathode ray printer. Input to the computer is in the form of punched cards, and output from the cathode ray printer is microfilm.

One objective of the system is to provide a do-it-yourself capability to mathematicians and programers who would like to do some printing of their own. Interest in the system is indicated by the fact that one or more parts of it have been acquired by personnel in 64 agencies. The system is written in FORTRAN, making it available to an especially large number of users. It resides in permanent files which may be attached to the computer by anybody in the laboratory. For each application there is a different main program. The user must be competent to write his own main programs.

Time limitations preclude a description of the system in any detail. Figure 1 outlines the system. The punched card input can be prepared by hand or generated through programing on the computer. There are versions which will run on any one of three computers. Output is primarily for the SD4060 cathode ray printer, but there are converters which have made it possible to obtain output on four other devices.

Figure 2 indicates input to the system. The first kind of input is cartographic data. There are digitizations of the world, the United States, and the Potomac River. The digitization of the world has come to be known as World Data Bank 0. The digitization is a simulation of an irregular coastline by a polygon. Along any side of the polygon the coast line wiggles from one side to the other. A measure of the amount of wiggle is a measure of the accuracy of polygonization. The philosophy of my polygonization was that the simulation should conform uniformly to a specification of accuracy over the whole surface of the Earth. Specification of an accuracy of 15 min of arc led to a world data bank with 8,000 data. By contrast, World Data Bank I contains 56,000 data for coastlines on a Mercator projection. Thus the CIA world is 7 times as fine as my world; their accuracy should be on the order of 2 to 3 min of arc.

The conventional way to define the fineness of digitization is to state the scale of map for which it is appropriate. If one map were plotted on a postage stamp and another projected on the side of a barn, the scaling would be vastly different, yet the relative accuracy of the polygonization would be the same if both maps were derived from the same data bank. It is recommended that the accuracy of polygonization should be expressed in terms of the extent to which the coastlines actually deviate from whatever polygonization is used.

The second kind of input is calligraphic data. I have a complete occidental repertory and an oriental repertory with 600 Chinese characters. Each character in both repertories is simulated with polygons. The polygonization has required a considerable amount of artwork.

The third kind of input is control data, and there are three kinds of control data. A modal code sets the system into a plot mode or a print mode. Textual data tell the system what to print, and functional data tell the system how to print. There are only 48 characters in the FORTRAN character set, and these are used to evoke 1,377 symbols under control of the functional data. There is a mnemonic code to express the functional data.

In printing a report, there are two streams of control data. The continuous stream of text data is interrupted at the bottom of every page by the insertion of folio data. There is a basic input deck which has one slot to receive text data and another slot to receive folio data. The computation is under the control of a main program with subroutines.

THE FORTRAN TYPOGRAPHIC SYSTEM

INPUT

IBM Keypunch
Magnetic Tape

COMPUTER

| | | |
|---|---|---|
| IBM 360 | UNIVAC 1108 | CDC 6600 |

OUTPUT

S-D 4060

| | | |
|---|---|---|
| CalComp 718 | FR-80 | CalComp 1670 |

MS-6000

Figure 1

CARTOGRAPHIC DATA

| World | United States | Potomac River |
|---|---|---|
| WORLDFILE | | WORLDMAP |
| (Update) | | (Binary) |

CALLIGRAPHIC DATA

| Occidental Repertory | Oriental Repertory |
|---|---|
| CHARFILE | CHARDATA |
| (Update) | (Binary) |

CONTROL DATA

| Text Data | Folio Data |
|---|---|
| TEXTO Program | FOLIO Program |

MAIN PROGRAM

SUBROUTINES

| SYMTYPO | BINTYPO |
|---|---|
| (Update) | (Binary) |

Figure 2

Nonstandard input decks make possible an unlimited variety of combinations of textual material and graphical material.

The FORTRAN definition statements for the three principal subroutines are given in figure 3. The cartographic subroutine controls the plotting of charts; the textographic subroutine controls the printing of text; and the foliographic subroutine controls the printing of folio.

A perspective projection of the Earth after rotation through three Eulerian angles is illustrated in figure 4. The most spectacular demonstration of these globes is a movie in which the Earth is rotated about an equatorial diameter instead of the polar axis. A view of the Earth from the Moon is plotted in figure 5. This is the cartograpic equivalent of the shot of the Earth that CBS used in their news broadcasts.

Some of the symbols in the system are shown in figure 6; several are cartographic. My sales sample is shown in figure 7. The Russian word in the center column means complexity, and the Chinese word in the same column means calligraphy.

The first of a few exotics is illustrated in figure 8. A basic concept of the system is dividing a composition into patterns. Each pattern can be translated or rotated into position as a unit. Thus if we have a card deck which will generate Chlorophyll A, we have only to change one card to make it into a card deck for Chlorophyll B. The genetic code is illustrated in figure 9. It helps us to remember the fundamental structures in the double helix.

Components of electronic circuits are illustrated in figure 10. Each pattern in the set of components is represented by a card deck. By duplicating the card decks and inserting additional cards, the components are connected with lines to make a complete circuit diagram.

The power of the system to crank out equations is demonstated by figure 11. I counted the number of equations until I reached 1,000, and then I gave up. The first bit of printing with the system is shown in figure 12. The section lines of a ship are illustrated in figure 13. This is a mixture of textual material and cartographic material in a single pattern, all derived from a single input deck.

LeBlanc: I will address cartographic symbology in the context of an automated drafting system in operation in the Government of Ontario. What follows is a description of the system and an analysis--by no means thorough--of a few deficiencies of the general symbolization capability, applied to cartography. The system is a customized drafting system which may possibly serve a purpose other than originally intended. The issue, then, is one that some cartogaphers may be familiar with; namely, second generation use of a technology that was developed to produce graphics which are now only a subset of a broader graphic requirement.

The Gerber 1232 Automated Drafting System was developed for photogrammetric production at large scale, principally from 1:500 to 1:2,500, of monochrome engineering plans for highway planning, design, and con-

FORTRAN TYPOGRAPHIC SYSTEM

```
   SUBROUTINE CTGPHC (LW, KF, CF, CA, NI, NO, GNLTRN)
*********************************************************************
   FORTRAN CARTOGRAPHIC SUBROUTINE
*********************************************************************
   LW = WIDTH OF LINE (FORTRAN INTEGER)
   KF = FORMAT ARRAY (SYMBOLIC ADDRESS)
   CF = FIELD ARRAY (SYMBOLIC ADDRESS)
   CA = AREA ARRAY (SYMBOLIC ADDRESS)
   NI = INPUT TAPE NUMBER (FORTRAN INTEGER)
   NO = OUTPUT TAPE NUMBER (FORTRAN INTEGER)
   EXTERNAL GNLTRN (AQ, FP)
   AQ = ARGUMENT ARRAY (SYMBOLIC ADDRESS)
   FP = FUNCTION ARRAY (SYMBOLIC ADDRESS)


   SUBROUTINE TXGPHC (NL, NI, NO, AI, AD, NR)
*********************************************************************
   FORTRAN TEXTOGRAPHIC SUBROUTINE
*********************************************************************
   NL = LINE NUMBER CONTROL (FORTRAN INTEGER)
   NI = INPUT TAPE NUMBER (FORTRAN INTEGER)
   NO = OUTPUT TAPE NUMBER (FORTRAN INTEGER)
   AI = INDEX ARRAY (SYMBOLIC ADDRESS)
   AD = DATUM ARRAY (SYMBOLIC ADDRESS)
   NR = RETURN NUMBER CONTROL (FORTRAN INTEGER)


   SUBROUTINE FLGPHC (NL, NI, NO, AI, AD, NR)
*********************************************************************
   FORTRAN FOLIOGRAPHIC SUBROUTINE
*********************************************************************
   NL = LINE NUMBER CONTROL (FORTRAN INTEGER)
   NI = INPUT TAPE NUMBER (FORTRAN INTEGER)
   NO = OUTPUT TAPE NUMBER (FORTRAN INTEGER)
   AI = INDEX ARRAY (SYMBOLIC ADDRESS)
   AD = DATUM ARRAY (SYMBOLIC ADDRESS)
   NR = RETURN NUMBER CONTROL (FORTRAN INTEGER)
```

Figure 3

Figure 4

FOURTH EARTHRISE DURING APOLLO 8 MISSION

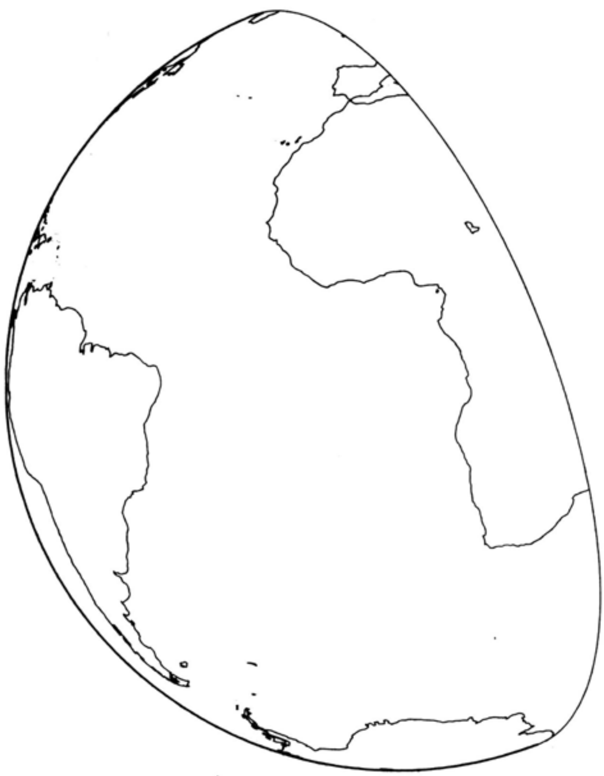


Figure 5

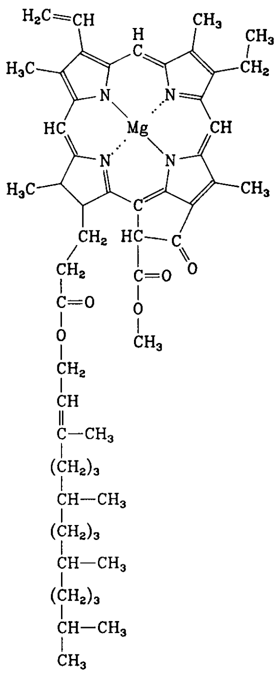

Figure 6


Invitation
COMMUNICATION
Publication
ECONOMY
VERSATILITY
Quality
CARTOGRAPHY
Standardization
TYPOGRAPHY
Γραμμα
Συμβολον
Αριϑμος
Графика
СЛОЖНОСТЬ
Фонетика
EXTENSION
Rotation
CONDENSATION
ROTATION
Syllabary
ΛΕΞΙΚΟΝ
Alphabet
Art
書道
Music
Meteorology
Wissenschaft
Astronomy
CHEMISTRY
Electronics
MATHEMATICS
Analysis
COMPUTATION
Program

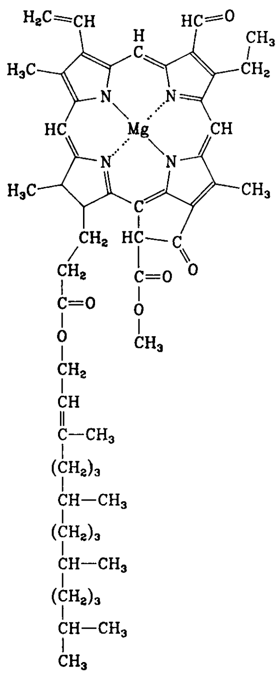
**Figure 7**

## STRUCTURES

CHLOROPHYLL A



CHLOROPHYLL B



ADENOSINE TRIPHOSPHATE

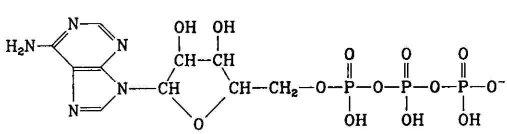


Figure 8

DNA

DEOXYRIBONUCLEIC ACID

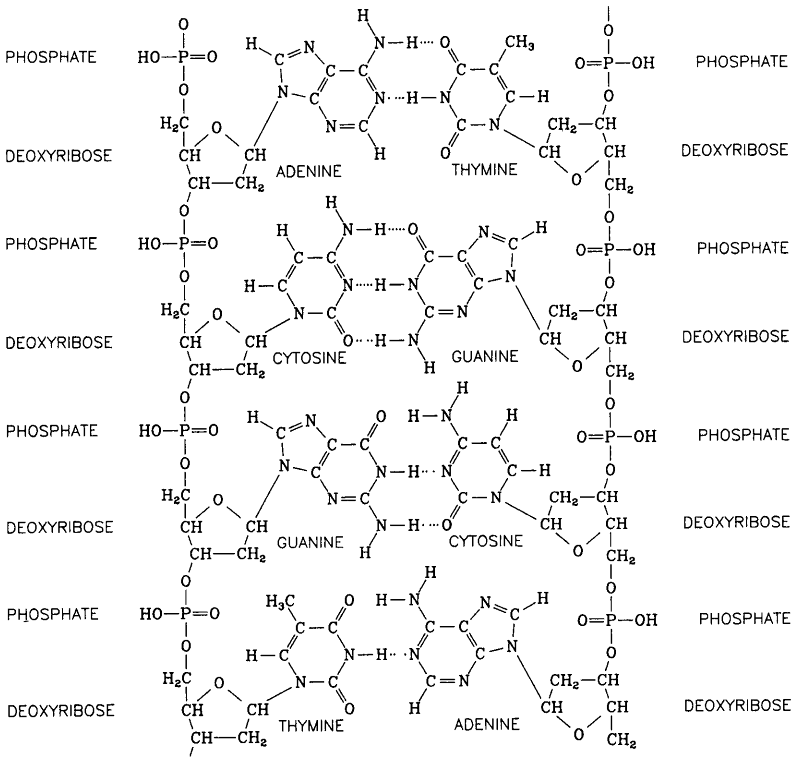



Figure 9

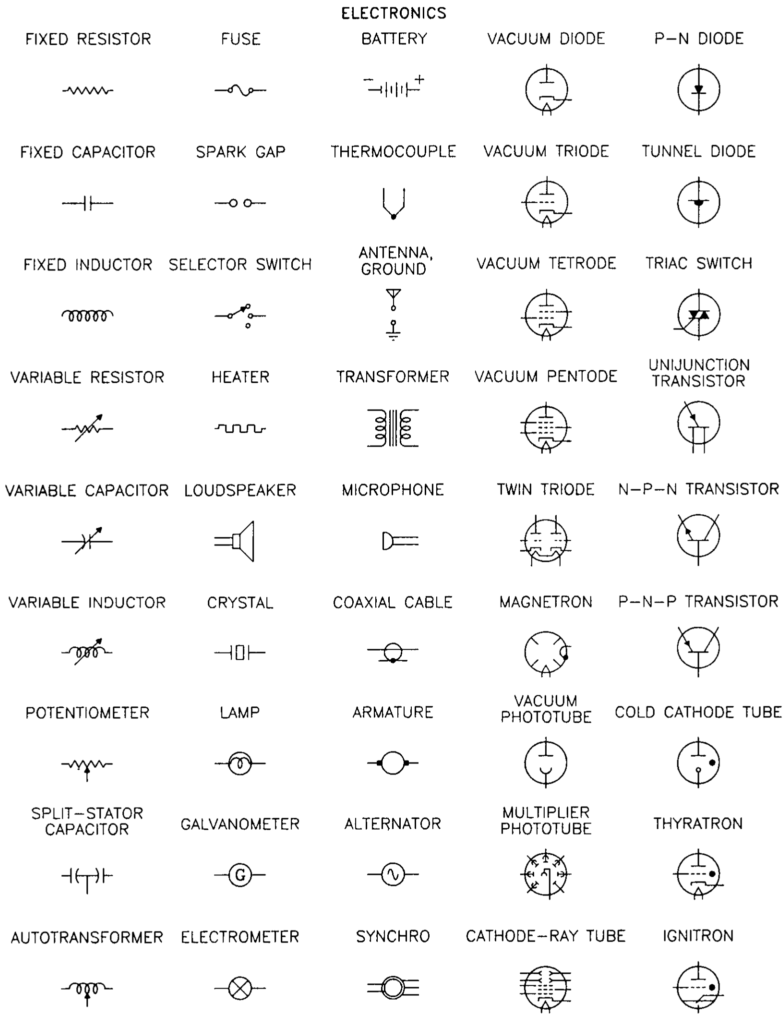

ELECTRONICS
FIXED RESISTOR
FUSE
BATTERY
VACUUM DIODE
P–N DIODE
FIXED CAPACITOR
SPARK GAP
THERMOCOUPLE
VACUUM TRIODE
TUNNEL DIODE
FIXED INDUCTOR
SELECTOR SWITCH
ANTENNA, GROUND
VACUUM TETRODE
TRIAC SWITCH
VARIABLE RESISTOR
HEATER
TRANSFORMER
VACUUM PENTODE
UNIJUNCTION TRANSISTOR
VARIABLE CAPACITOR
LOUDSPEAKER
MICROPHONE
TWIN TRIODE
N–P–N TRANSISTOR
VARIABLE INDUCTOR
CRYSTAL
COAXIAL CABLE
MAGNETRON
P–N–P TRANSISTOR
POTENTIOMETER
LAMP
ARMATURE
VACUUM PHOTOTUBE
COLD CATHODE TUBE
SPLIT–STATOR CAPACITOR
GALVANOMETER
ALTERNATOR
MULTIPLIER PHOTOTUBE
THYRATRON
AUTOTRANSFORMER
ELECTROMETER
SYNCHRO
CATHODE–RAY TUBE
IGNITRON

**Figure 10**

TABLE I

ELLIPSOIDAL INTEGRALS

$$X = \int_{\xi}^{\infty} \frac{d\theta}{\sqrt{4(a^2+\theta)(b^2+\theta)(c^2+\theta)}} = \frac{1}{(a^2-c^2)^{\frac{1}{2}}} \int_0^{\phi} \frac{d\varphi}{\sqrt{1-k^2\sin^2\varphi}} \quad (1)$$

$$A = \int_{\xi}^{\infty} \frac{d\theta}{(a^2+\theta)\sqrt{4(a^2+\theta)(b^2+\theta)(c^2+\theta)}} = \frac{1}{(a^2-c^2)^{\frac{3}{2}}} \int_0^{\phi} \frac{\sin^2\varphi\, d\varphi}{\sqrt{1-k^2\sin^2\varphi}} \quad (2)$$

$$B = \int_{\xi}^{\infty} \frac{d\theta}{(b^2+\theta)\sqrt{4(a^2+\theta)(b^2+\theta)(c^2+\theta)}} = \frac{1}{(a^2-c^2)^{\frac{3}{2}}} \int_0^{\phi} \frac{\sin^2\varphi\, d\varphi}{(1-k^2\sin^2\varphi)^{\frac{3}{2}}} \quad (3)$$

$$C = \int_{\xi}^{\infty} \frac{d\theta}{(c^2+\theta)\sqrt{4(a^2+\theta)(b^2+\theta)(c^2+\theta)}} = \frac{1}{(a^2-c^2)^{\frac{3}{2}}} \int_0^{\phi} \frac{\sin^2\varphi\, d\varphi}{\cos^2\varphi\sqrt{1-k^2\sin^2\varphi}} \quad (4)$$

$$L = \int_{\xi}^{\infty} \frac{d\theta}{(b^2+\theta)(c^2+\theta)\sqrt{4(a^2+\theta)(b^2+\theta)(c^2+\theta)}} = \frac{1}{(a^2-c^2)^{\frac{5}{2}}} \int_0^{\phi} \frac{\sin^4\varphi\, d\varphi}{\cos^2\varphi(1-k^2\sin^2\varphi)^{\frac{3}{2}}} \quad (5)$$

$$M = \int_{\xi}^{\infty} \frac{d\theta}{(c^2+\theta)(a^2+\theta)\sqrt{4(a^2+\theta)(b^2+\theta)(c^2+\theta)}} = \frac{1}{(a^2-c^2)^{\frac{5}{2}}} \int_0^{\phi} \frac{\sin^4\varphi\, d\varphi}{\cos^2\varphi\sqrt{1-k^2\sin^2\varphi}} \quad (6)$$

$$N = \int_{\xi}^{\infty} \frac{d\theta}{(a^2+\theta)(b^2+\theta)\sqrt{4(a^2+\theta)(b^2+\theta)(c^2+\theta)}} = \frac{1}{(a^2-c^2)^{\frac{5}{2}}} \int_0^{\phi} \frac{\sin^4\varphi\, d\varphi}{(1-k^2\sin^2\varphi)^{\frac{3}{2}}} \quad (7)$$

$$P = \int_{\xi}^{\infty} \frac{d\theta}{(\theta-p)^2\sqrt{4(a^2+\theta)(b^2+\theta)(c^2+\theta)}} = \frac{1}{(a^2-c^2)^{\frac{5}{2}}} \int_0^{\phi} \frac{\sin^4\varphi\, d\varphi}{(1-\alpha^2\sin^2\varphi)^2\sqrt{1-k^2\sin^2\varphi}} \quad (8)$$

$$Q = \int_{\xi}^{\infty} \frac{d\theta}{(\theta-q)^2\sqrt{4(a^2+\theta)(b^2+\theta)(c^2+\theta)}} = \frac{1}{(a^2-c^2)^{\frac{5}{2}}} \int_0^{\phi} \frac{\sin^4\varphi\, d\varphi}{(1-\alpha^2\sin^2\varphi)^2\sqrt{1-k^2\sin^2\varphi}} \quad (9)$$

Figure 11

## RELATIVITY

That the velocity of light is independent of the motion of the observer was indicated first by the experiments of Michelson and Morley The constancy of the velocity of light is only one manifestation of the principle of relativity, which may be stated in the following way

*It is not possible by any physical experiment to determine an absolute motion through space*

An implication of the principle of relativity is that all scalars, vectors, and tensors which represent physical quantities are invariant with respect to the speed of the reference frame to which they are referred

Let a spherical light wave emanate from an origin of coordinates at zero time and expand with the speed of light The equation of the light wave is

$$x^2 + y^2 + z^2 - c^2t^2 = 0 \quad (1)$$

where $x, y, z, t$ are the Cartesian coordinates and the time of a point in the light wave and $c$ is the speed of light. Invariance of the scalar function in Equation (1) implies that a position vector $\mathbf{r}$ with coordinates

$$(x, y, z, ict) \quad (2)$$

is invariant in a four-dimensional space whose metric is given by the equation

$$(dl)^2 = (dx)^2 + (dy)^2 + (dz)^2 - c^2(dt)^2 \quad (3)$$

The vector $\mathbf{r}$ may be differentiated with respect to the metric $l$ to obtain new invariants which satisfy the identity

$$\frac{d}{dl}\left(\frac{d\mathbf{r}}{dl}\,\frac{d\mathbf{r}}{dl}\right) = 2\,\frac{d\mathbf{r}}{dl}\,\frac{d^2\mathbf{r}}{dl^2} = 0 \quad (4)$$

Associated with a particle is a rest mass $m_0$ which is a physical quantity and is invariant by the principle of relativity Associated with the particle is a momentum vector $\mathbf{p}$ which may be defined by the equation

$$\mathbf{p} = im_0c\,\frac{d\mathbf{r}}{dl} \quad (5)$$

Application of the Identity (4) to the momentum vector $\mathbf{p}$ leads to Einstein's law of the equivalence of mass and energy. The prediction of the equivalence of mass and energy is one theory which has been confirmed in the most spectacular way by practical applications It gives the source of energy for nuclear bombs

Figure 12

BODY PLAN

$B = 2\ 666$ $H = 1\ 067$

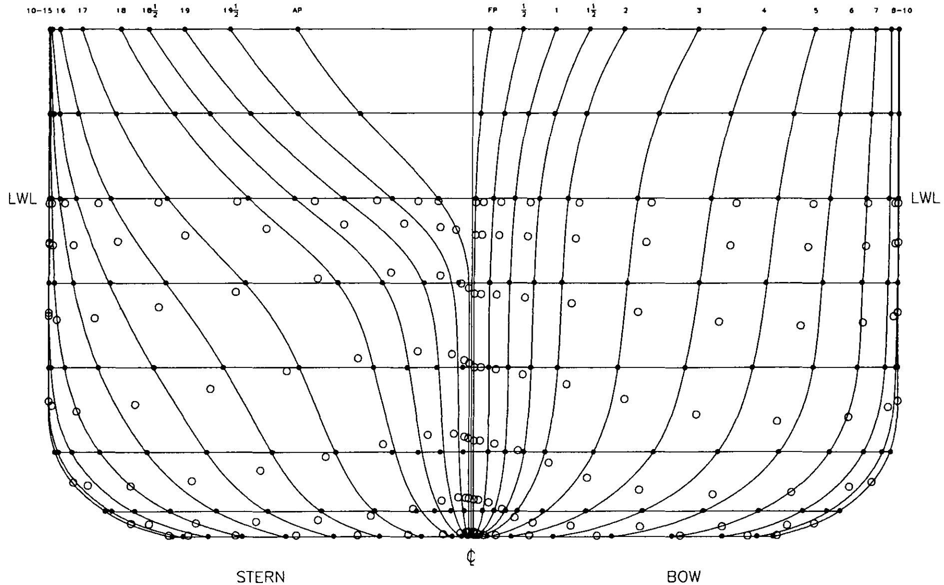



Figure 1 Section Lines of Series 60, Block 0 60 Ship Model •, Tabular Offsets from NSRDC Report No 1712, –, Orthonormal Polynomial Representation, o, Coordinates for Chebyshev Spacing along Section Line and along Longitudinal Axis

struction in the Ontario Ministry of Transportation and Communications. Figure 1 shows the hardware configuration. Three-dimensional data are obtained off-line (on 7-track magnetic tape) from four Zeiss D2 planimats interfaced to Wang 2300 and GRADICON digitizers; the two-dimensional digitizing units (Coordinatograph, Instronics) are not included in the diagram. The central processer is a Hewlett-Packard 2116 with the peripherals shown. The plotter is a Gerber 32 flatbed.

Figure 2 is a portion of a standard plot at a scale of 1:480, now being converted through the metrication program to 1:500. The range of symbolization at this scale is demonstrated. The less obvious cloud-like symbols are deciduous trees which are plotted using a center-point-radius software routine. The simplicity of the overall product is rather evident.

Figure 3 is a slightly generalized plot at a scale of 1:2,400. Most of the symbols that are presently used are revealed on this particular plot. Figure 4 is a portion of a 1:10,000-scale plan; this is not the normal output scale but is shown here for comparison. It is possible to generalize data to an even smaller scale.

Figure 5 is an experimental sheet which was produced to demonstrate medium-scale data handling capability and a multicolor product. It is simply an attempt to duplicate a topographic sheet (minus most typography) of the Peterborough area of Ontario at 1:25,000 scale. The photographs were taken, digitized, and plotted for this particular scale. Note that most of the symbology, such as point symbols, is extremely generalized; for example, buildings are shown as dots rather than as rectangles which are used at larger scales.

My Cartography Section has been offered the use of this system as technical support in the production of 1:250,000-scale multicolor transportation maps (fig. 6). There are certain symbolization problems inherent in this new production requirement. First, there is the dichotomy of symbol character caused by the need for generalization: those symbols which are presently plotted according to a definition in a symbol library versus those symbols which are flashed. If the same data that are used for large-scale plan plots were used for smaller scale maps (e.g., the 1:250,000-scale transportation maps), a problem arises when a software-defined symbol is perhaps better plotted at a smaller scale using a flashed symbol. At what scale and in what manner the symbol definitions change have not been established for all features.

The image font of the optical exposure head of the Gerber 32 has a capacity of 24 images, some of which are presently used for linework and others for relevant point symbols. Much symbology is software-generated, including lettering. At a smaller scale, however, a greater number and variety of line, point, and alphanumeric symbols are needed; most would be simple and lend themselves to being flashed, but the 24-image capacity would be vastly exceeded. Recent research and development have perhaps provided an answer to the need for various type faces, but potential incompatibilities are not known. Another liability is the nonrotation of the photo-head, which further limits the possibilities of orienting the symbols. Also, there is no interactive display/edit capability for error and interference detection; the latter is much more of a problem with small-scale maps than with plans.

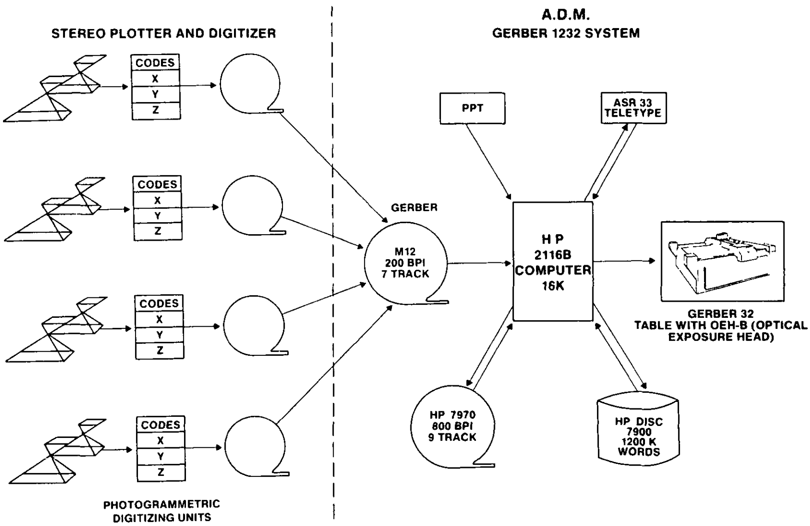



Figure 1.--Hardware configuration for Automated Drafting System (After MacLeod and Turner, 1971).

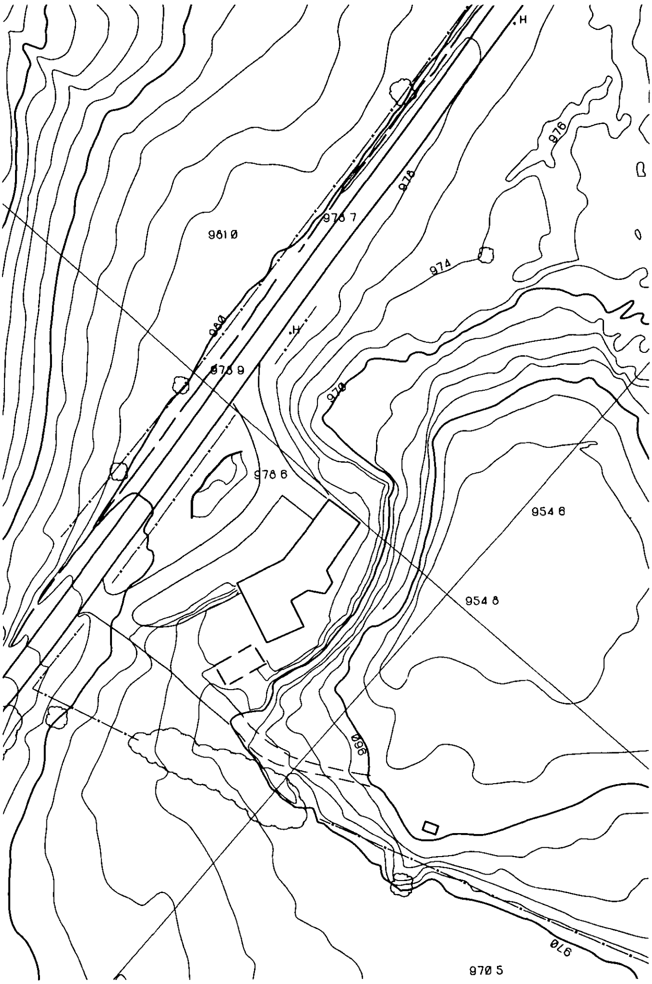



Figure 2.--Portion of an ADM plot at a scale of
1:480 with a 2-ft contour interval.

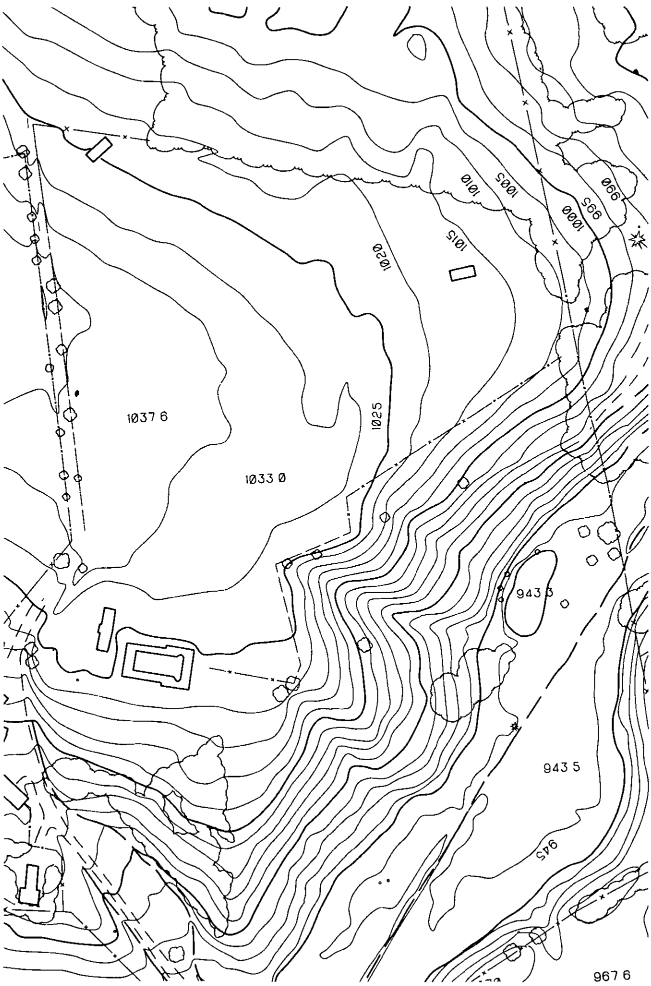



Figure 3.--Portion of an ADM plot at a scale of 1:2400 with a 5-ft contour interval.

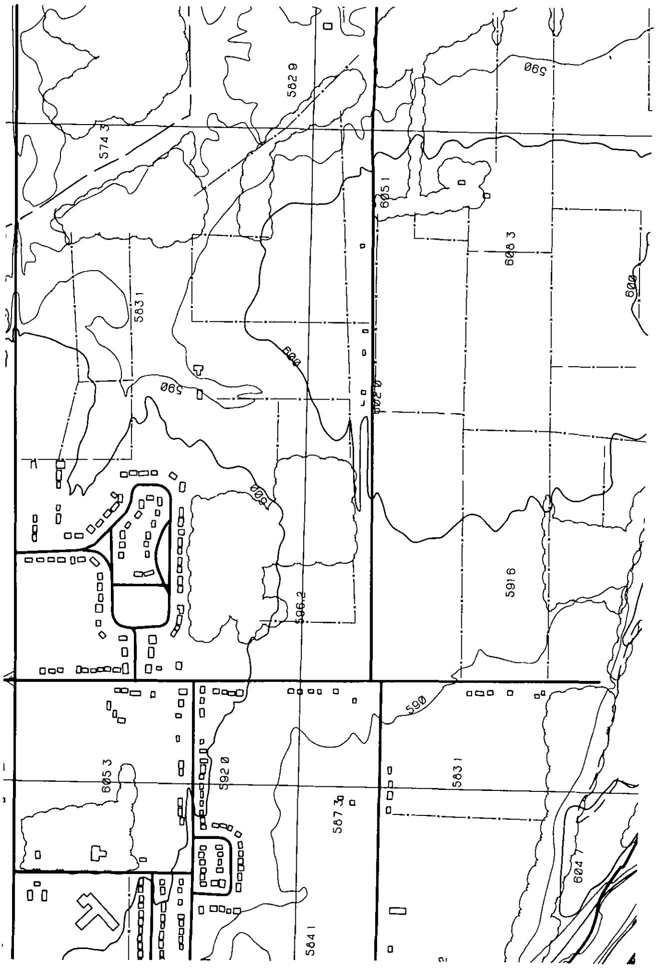


Figure 4.--Derived plot at 1:10,000 scale. Note that each building remains plottable as a unique feature.

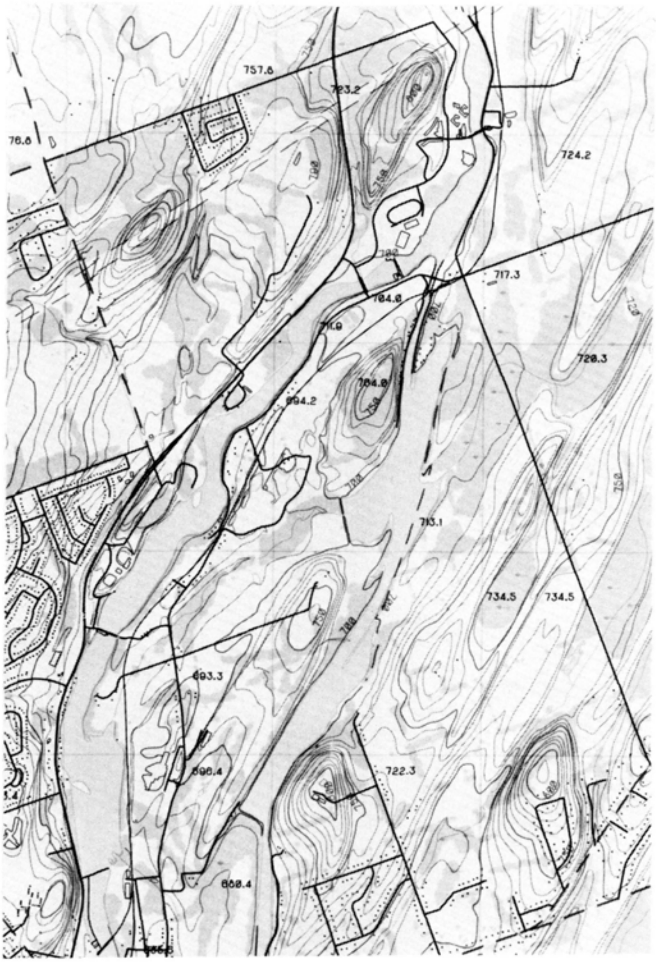



Figure 5.--Small section of a 1971 four-color experimental map, duplicating the area covered by a National Topographic System 1:25,000 sheet. Pre-punched matte autopositives were sequenced manually on the plotting table; peelcoats were etched subsequently.

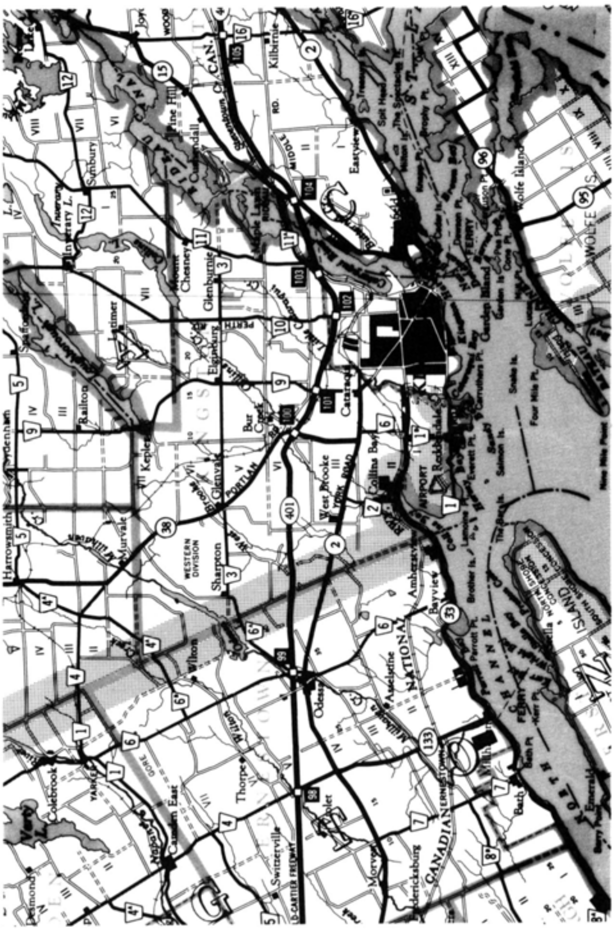



Figure 6.--Section of a conventional four-color planimetric transportation (road) map at 1:250,000 scale.

A second observation concerns the digitizing and coding procedure. The basic record currently recognized by most software is a product of: a code that identifies the feature; a subcode that is simply a sequential numbering of features within a code, which is used to turn on/off the optical exposure head as it moves from one feature to the next; an accuracy code which reflects the scale of original digitizing and is ultimately useful in generalization subroutines; and the x, y, and z coordinates.

CODE + SUBCODE + ACCURACY CODE + COORDINATES
+ OPTIONAL ANNOTATION = RECORD for one point.

The structure is a general-purpose one and should accommodate extended usage with limited difficulty.

A third consideration is that there is not a demand for symbology in engineering plans, so much as extensive use of area tints. To mechanically plot the area tints needed for transportation or other maps, it would be necessary to introduce some sort of systematic and efficient "beaming" algorithm whereby an area is beamed and a peripheral mask is used to limit the "scalloped" edge. This capability is not available now but is certainly obtainable.

The concept of image repeatability (or table registry) is particularly important to the color separation of 1:250,000-scale maps. Adjacent areas plotted on separate pieces of film must join, so that the repeatability of the line separating them is crucial. Of course, the Gerber plotter possesses good repeatability.

There is a commitment inherent in the present system to duplicate the manual method. This system philosophy has led to a particular hardware configuration, data handling capability, and software which reinforce the use of the system as technical support and not as an alternate production system which could create, perhaps, unique or better graphics.

Johnson: The Soil Conservation Service has a digitizer, computer-probe software, and a Gerber drafting machine. I have four different character sets which fall somewhere between the symbology described by Hershey and LeBlanc. Our publication, "Symbology for Mapping," shows all the symbols we use for boundaries, hydrology, transportation, utilities, highways, and soils.

(Unidentified speaker): Mr. LeBlanc, I noticed two things in the last slide (fig. 6). The first one you commented on is that the houses are circular dots; the second is that the streets appear to be all single lines. I won't say that it is conventional to show double-line streets and square houses, but I wonder if you have received any adverse commentary about that particular choice of symbols and, if so, are any of them in you opinion really valid?

LeBlanc: Yes, and yes. The house symbol is round simply because the beam is round; for the time being there is no capability for squaring off the beam. That is one of the problems with using a beam to flash across an area symbol; the beam surpasses the limits of that area and you have to use some manual knockout procedure to limit it. At that scale, which by the way was experimental, there really wasn't much point in trying to get a particular type of sophistication. Double-line streets, which are relevant to the color products that I produce, are a problem. At the scale of engineering plans, both sides of a road are digitized separately and plotted that way. For smaller scale mapping, digitizing down the center or generalizing from two sides (i. e., calulating from a center point and then plotting parallel lines) are being investigated. One possible resolution is to use a beam-splitting mirror to create a double line.

Forstall (U.S. Forest Service): I have been doing a little bit of work programing this sort of symbolization. I would be delighted to talk to you, sir, and to anybody who is interested in exchanging further ideas on the subject.

# Announcement

André Guillaume
Pierre and Marie Curie Institute

I want to make you aware of the first report on automated cartography in the official and private services of France. The preprint of this report was distributed at the Madrid conference. The report is presently being edited by the French Committee of Cartography. Although it is impossible to present the entire report here, I want to give you an idea of what it will cover.

Concerning graphic data acquisition, the trend is to extensively utilize the graphic properties. I see here some analogy with works of Harvard University and the DIME system.

Concerning data processing, the trend is to develop algorithmic methods for interpolating and smoothing. Methods include correspondence analysis, a kind of factorial analysis, and dynamic clustering of elements for selecting or grouping the data. I might also mention some routines developed in specific languages adapted to graphic programs.

If you want more information, particularly how to obtain the report, please contact me.

## Geographic Information Systems Panel

Robert T. Aangeenbrug, Presiding
Bureau of the Census

William B. Mitchell
U.S. Geological Survey

Duane K. Marble
State University of New York at Buffalo

Alden C. Gunther
U.S. Army Engineer Topographic Laboratories

Mitchell: After yesterday's interdisciplinary warfare between cartographers and mathematicians, I began feeling comfortable that I am a geographer and maybe out of the line of fire. My comfort was destroyed by a help-wanted ad in Sunday's paper in which the Central Intelligence Agency listed needed skills--accounting, business administration, chemistry, and foreign language with high proficiency required in Arabic, Chinese, French, Italian, Japanese, Korean, Geography, and Polish. Now I know what my problem has been; I've been speaking a foreign language.

This year is the first time since the 1800's that the U. S. Gelogical Survey has had a geographic organization. Our primary program, Land Use Data and Analysis (LUDA), has been funded for the first time by Congress this fiscal year. The program will extend over the next 5 or 6 years with the rather grandiose objectives of mapping land use and four other data categories for the entire U.S.--635 1:250,000 sheets. After 5 yr, providing we last that long, these maps will be updated. In addition we will produce sheets at 1:50,000 and 1:25,000 for areas of more rapid change and of more concern in land-use planning and resource management.

To accomplish these objectives, the geography program staff was organized into three teams: interpretation and compilation, geographic information systems, and research and analysis. The interpretation and compilation staff produces the overlays: land use, Federal-land ownership, river basins and subbasins, counties, census county subdivisions, and State-land ownership if available. The data bases of the maps at larger scales will presumably have the same breakdown. When these maps have been compiled, the plan is to have them digitized to build a data base from which graphic displays and statistical data on current land use and cover can be provided to States on request. The scale of 1:250,000 was chosen, partly because of interested planning groups around the country but mainly because only at this scale is there complete map coverage of the U.S. To start we wanted to produce at least one overlay in every State. Production is currently funded through cooperative agreements with the States.

The geographic information system was started some time ago along with the EROS program. Our present objectives for LUDA are to process the maps produced on a batch basis and to produce statistics and graphics. If you have been on a USGS tour, you may know that we have acquired the equipment and are using Boyle's interactive cartographic and geographic information system.

We are using this interactive system for two reasons. First we would like to have such a system available to our research and analysis staff, which primarily consists of research geographers. With such a system they would be able to produce digital maps as they need them and to produce clean data, which can be manipulated to support geographic analysis, environmental impact analysis, etc. Second, we hope that such a system can be used to investigate "what if" problems and land-use and resource-management problems.

Marble: Automated cartographic and geographic information systems are obviously in the early development stage. Unfortunately there is much duplication of effort and little transfer of information. This is where the International Geographical Union's Commission on Geographical Data Sensing and Processing gets involved. The Commission is an informal group associated with many international scientific unions. Our concern has largely been the handling and processing of spatial data. In the last 5 yr we have been interested in implementing technology transfer. Some of us are geographers and some represent other fields, but we all have a common interest in the techniques and problems of acquiring, storing, manipulating, and displaying spatial data. To improve technology transfer, the Commission has sponsored many activities. A conference was held in Ottawa a few years ago to summarize the state of the art. This conference produced a two-volume book, called Geographical Data Handling, which has had a wider distribution than we anticipated.

The Commission, headed by Dr. Roger Tomlinson of Ottawa, is made up of working groups which are established as problems are encountered. The number of people in each group ranges from 3 to 100. We are concerned with improving technology transfer and impartially evaluating activities. At the Ottawa meetings we published a comprehensive directory of individuals involved in this area. I have just finished updating it, and soon the Commission will release the new directory. We are also compiling a directory of cartographic and geographic information systems.

One working group has recently finished a series of indepth case studies of land-use information systems. These case studies have covered such successful operating systems as the Canada Geographical Information System, systems in New York and Minnesota, and others. We hope to release these case studies soon so that people will know the problems, successes, and failures of these systems. Our concern ranges from specialized hardware considerations to policy considerations to integration of the information system into government decisionmaking.

At present several working groups are reviewing land-use and natural-resource information systems. We are again reviewing specialized hardware hardware considerations in computerized systems, and we are working on a software directory. We also have Cliff Fry of the USGS working with us in reviewing the manual methods of handling this type of data.

We are deperately interested in learning what you are doing because technology transfer is hampered without a broad information base. If any of you have not been contacted by the Commission or don't know what we are doing, we would be delighted to hear from you.

Gunther: After 4 yr of work the Engineer Topographic Labs have developed the System for Topographic Information (STOPIN). For our use, topographic information includes both pure geographic and military geographic information as well as the information normally contained on a military topographic map. Thus topographic information is a broader term than terrain or intelligence information. If you will give me your name and mailing address, we can include you in the distribution of the technical documentation for STOPIN.

STOPIN is an interactive storage retrieval system for geographic information in alphanumeric form. It was originally designed to support the terrain intelligence functions of the Army in the field and was later modified to support the production of standard and special topographic products. The system can be the vehicle for maintaining large quantities of alphanumeric geographic information until or before a map is produced and for storing information collected during the cycle of a map edition. It could also provide a means of production for a map errata sheet, similar to the Notice to Mariners. STOPIN consists of 18 data fields with over 1,700 data elements in each. Each data field is a unique subject of natural or cultural information, ranging from air terminals to vegetation. The system is based on a geographic unit the size of a standard military topographic map of 1:50,000 scale (about 640 ). We employ variable length records which are implemented with a variable block concept. Each of the 26 unique record structures in the system has a fixed and a variable portion. Information that is always present if the feature or phenomenon exists is contained in the fixed part. For those elements which are feature dependent, or for which there is no prior knowledge of how many occurrences will exist, information is stored in the variable part. Record lengths in the system vary between 60 and 20,000 characters. All of the information is stored in packed binary format on disk and expanded when processed.

The STOPIN software is modular, allowing implementation of 1 to 18 data fields as long as one copy of the main program is in residence. The system consists of an executive and 8 primary overlays--4 are unique to each of the data fields, and 4 are common to all fields. STOPIN was written in FORTRAN, and the data base is indexed sequentially. The records in the data base are keyed by data field (an alpha code from A through Z), map sheet number, and feature identification. The system includes a major key search option which allows searching on the data field and the map sheet. For instance, this option allows all buildings to be listed within a given sheet.

The system operates on the CDC 6600, under the SCOPE operating system. One report in the documentation series provides a test of the conversion to the Univac 1108 and reveals basic problems encountered during conversion. It provides a sample version of one program for each computer and shows which changes must be made. Although this system is quite large (we wrote approximately 75,000 lines of code during the development, 28,000 of which are used during the operational version), the complete software package will operate interactively under INTERCOM, requiring less than 75,000 words of core.

As a computer systems analyst who is concerned with information, I would like to emphasize the importance of geographic information systems and to define the purpose of the designers of such systems. The primary purpose of any information system is to provide the user with the required information. Systems must be developed with purpose and defined from the beginning. In come cases, however, requirements will distort all purposes and even negate many design features established for those requirements. Regardless of the problems created by working in a dynamic environment, we as systems designers must always attempt to provide the user with the required information in the desired format. My purpose as a designer of geographic information systems is to provide the user with a tool for storing, retrieving, and manipulating the required information economically and efficiently.

Aangeenbrug: Information is the most powerful tool at the disposal of local government officials, but many of us have problems communicating with these people. The word systems turns off most of the local authorities. Systems is a catchy word that usually means a lengthy discussion which most elected officials don't have time for or should not take the time for. We have a lack of clarity in our profession, and I'm pleased to hear that we are beginning to improve this situation. An enormous amount of confusion is heaped on beleaguered city officials, who have to solve the problems that Federal officials talk about. Saying that we're studying 50 independent State systems but can't take any Federal leadership confuses and embitters the local authorities. As a result they are beginning to send messages, one of which is the Moorhead bill, that say, "I don't care what your agency does, please help; if you don't, I'll require you to do so." This message is important because it will require us to improve professionalism. An elected official doesn't really care whether a cartographer or a mathematical physicist solves the problem as long as he gets the job done. The elected officials want answers to problems, not problems to problems. They don't want to know how accurate something ought to be or if the DBF DIME works or not. They don't care if it doesn't work.

The lack of operating successes is a second frustration. Some fantastic "geoplan" and super-duper systems are still being peddled that were documented prior to completion. Don't document a system that isn't complete. At subsequent meetings such as this one, maybe we should have local officials criticize our work. We need to be examined under the more critical eye of people who have the daily problem, not by long distance from Washington.

A third problem is people. We have to share credit, and let other people take credit even though we may feel that we are not getting our share.

Fourth, hardware costs are still a problem. Even the price of a plastic bottle is rather high in River City. We must encourage technology transfer experiments that will allow people to share plastic bottles. Universities and Federal and State officials will have to take risks and help local authorities.

The fifth problem is software. The lack of standardization is the most vexing problem. Next the documentation is usually written in a language almost impossible to understand. If you're learning FORTRAN, for example, you have to learn it experimentally. I would urge IDU, similar organizations, and perhaps this conference to prepare short statements written in English that policymakers can understand.

Dr. Mitchell, it might be useful if we knew what documentation is available on LUDA and where it can be obtained.

Mitchell: The documentation on LUDA is rather good regarding long-range plans but rather transitory regarding exact plans. We are focusing more on the problem of documentation, and we are trying to inform people about the program. For example, seminars will probably be held in April 1975. Local planners are invited for a 2-day seminar concerning their problems and our plans for solving these problems. This series of seminars is similar to those held a few years ago on the land-use classification system. I plan to release additional information on the geographic information system of the LUDA program, but for general information, write the U.S. Geological Survey, National Center, Stop 115, Reston, Virginia 22092.

Gunther: I'm pleased to see that the work of the Army Engineer Laboratories is being released. One problem in technology transfer has been the question of public and private information. The more information that we get in the open to examine and to learn from, the faster we will progress.

Aangeenbrug: Local governments are also concerned and confused because various Federal agencies have requirements that overlap. This overlap is a serious problem, and I'm glad to see that Federal agencies are communicating here. Second, local people continue to wonder why the Federal Government does not exhibit more cooperative public efforts in such areas as geographic information systems. They are not particularly eager to hear how much time it will take to report on one more task force. I urge you to stimulate your agencies to exhibit your cooperative efforts. By the way, it is also true that local officials take advantage of the duplication of efforts. The mayor of Denver received $3,000 for the same thing from 3 different agencies. Local officials with administrative talent like the confusion because they can manipulate it to their advantage.

# General Sessions

## Governmental Implications of Automation Panel

Roger F. Tomlinson, Presiding
Chairman, IGU Commission on Geographical
Data Sensing and Processing

Arthur L. Ziegler
Wisconsin State Cartographer

Rupert B. Southard
U.S. Geological Survey

Ziegler: Wisconsin established the position of State Cartographer to coordinate mapping innovations. My duties are to collect and assimilate information regarding innovations in cartographic techniques and mapping programs, to keep abreast of the progress made by mapping agencies, and to promote liaison among municipal, county, State, and Federal mapping agencies. Since I was recently appointed to the position (August 1974), I am not yet able to speak with authority on this subject, but I have been involved to some extent with the mapping activities of the local governments in Wisconsin.

There is very little, if any, automated cartography at the local level. Local governments in our State depend entirely on the State government for automation. In Wisconsin there is some automation in the universities and in some of the State agencies such as Transportation. But they are basically modifying or adapting programs, procedures, or equipment that someone else has researched and developed. The State and local governments depend on the Federal Government to lead the way in automated cartography. The local governments do not have the money nor are they equipped to get deeply involved in the research necessary for developing cartographic automation, even though they have a tremendous need for it.

We have regional planning commissions in Wisconsin, comprised of several counties, whose main responsibilities are land-use and regional planning. People on these planning commissions have limited cartographic knowledge. For example, a regional planner would like to have a base map printed by an automated plotter and 10 yr of land use digitized in yearly increments. He would prefer to publish land-use data in several formats. However, he has no equipment except access to a high-speed printer at a local university. He has read all the literature about automated cartographic development, but he doesn't know where to get the equipment or who can get it for him. Plus, his budget is only about $5,000 for the whole project.

The important point is that an automated base, with land use digitized so that he could add to it each year, would help tremendously in future planning. Then he could make vital person-to-person decisions at the local level. Probably his only source of funds will result from appealing to the local governing board or qualifying for support such as the Housing and Urban Development Act 701 fund. But if he doesn't know where to seek assistance, he is lost and often reverts to the ordinary pen-and-ink, one-copy, hand-colored map that hangs in the office. Thus the product of his land-use planning program is one map that will not be distributed to those who could use it.

In its development of automated cartography, the Federal Government must keep in mind the needs of the local planners and aim for maximum utilization.

Southard: It is important to note that, in an attempt to hasten and improve the communication between mapping agencies, two States--Colorado and Wisconsin--have set up the position of State Cartographer. I am delighted to see this. The State Cartographer will be able to determine the needs of State users and to make these needs known to Federal data-collection and cartographic agencies. The Federal Government must become more aware of the problems of all users in understanding and getting accurate cartographic data in the desired form. The Federal Government must also play a leading role in developing and maintaining the system to determine current needs and respond to them. There is reason for hope. Some evidence for my optimism is the work of the Federal Mapping Task Force, which was convened by the Office of Management and Budget (OMB) in April 1972. The Task Force was headed by Emory Donelson (OMB) and included representatives from the Departments of Agriculture, Commerce, Interior, and Defense, and the Central Intelligence Agency. In addition about 50 other professionals and specialists of the Federal mapping, charting, and geodesy community were consulted.

The Task Force had four major objectives: to examine civil and military domestic mapping, charting, and geodesy (MC&G) activities, objectives, and supporting research and development; to determine how to better use resources; to formulate, on the basis of findings a comprehensive national program of MC&G that could efficiently meet the needs for maps, charts, and data; and to structure an organization that could carry out the MC&G programs. Of course, while the Task Force study was in progress, the need for data at all levels in any form increased dramatically.

During the study we examined processes, products, and user satisfaction at all levels. Our user survey was, we admit, a microcosm of what it should have been, but it revealed what we needed to know rather quickly. Not many users at any level were very satisfied with content, form, or currency of product, with the speed with which they could get it, or with their own comprehension. The Federal Government's ability to deliver products and data had fallen far short of the growing need; nature of the need had changed and was continuing to change.

The Task Force found that, in 1972, 39 Federal agencies of 7 Departments and 11 independent agencies spent $305 million and expended 13,000 man-years in MC&G activities. In addition, another $142 million was spent on related activities in other fields--soils, oceanography, and geology. There was no one in charge, no overall coordination, and no program review. The proliferation of agencies' capabilities to meet their own MC&G requirements continued because they weren't getting what they needed from the agencies charged with meeting those requirements. There was no central source of MC&G data and no mechanism for identifying and evaluating requirements. Also the research and development effort was small and fragmented, and communication both within and outside the Federal community was poor.

The Task Force concluded that the way to solve all of these problems was to organize a strong central MC&G agency, but this hasn't happened yet. Such an agency could well be placed in a proposed new Department of Energy and Natural Resources, but that hasn't happened yet either.

We also concluded that the civilian community needs to make more and better use of advanced technology in all fields. We had just barely left planetable technology and were content with the Kelsh plotter, the PG2, and the B8, but we hadn't progressed much further in any innovative way. I'm exagerating only slightly to make a point. We need to expand and coordinate civilian experimental mapping and surveying. We also need to expand uses of automation, data processing, and dissemination of data. Finally we must furnish a central source for map and survey data.

I won't give you a laundry list of all the good things that are happening as a result of the Task Force investigation. Nothing has reached fruition, but much has been started. Communication between Federal agencies has improved. The "not-invented-here" syndrome is being reduced if not eliminated. We haven't done all that we need to do in distributing products, data, advice, and knowledge, but we recognize the need. At USGS we have formed the National Cartographic Information Center to furnish a central one-stop source for all kinds of cartographic data, and we have arranged with other data holders for access to their data bases. After 6-mo work on this 10-yr job, we are finding that most agencies are eager to make their data available and assist in improving public awareness.

What does the future hold? My crystal ball is cloudy today. Yours is as good as mine, but I'll tell you how the situation looks to me. At least 12 agencies recognize that we data producers must find a way to make our products available to the public and to each other so that we can avoid duplication at great expense. Although necessary research in automation will be very costly, the payback will be immense. The major funding should be Federal, and I believe that fact is recognized. The speed with which these funds will be made available is in the lap of the gods. We will try to distribute funds according to need and to keep users abreast of research development at all government levels. Finally, we'll actively educate all in the effective use of these capabilities. For our plans to work, however, users or their spokesmen must clearly communicate their needs and problems. If we don't understand you the first time, come back, and if we don't understand you the second time, come back again. If we don't understand you the fourth time, write your congressman. Then we'll try harder. Contacts that you've made at this conference must be aggressively pursued. We recognize that interaction is often difficult, but we'll do everything that we can to facilitate it.

Tomlinson: The role of a State Cartographer, as Ziegler described it, is essentially passive. Only a minor part of his task is liaison with the Federal Government. Yet the States and particularly the local governments must tell the Federal Government their needs--whether they be products, advice, or the transfer of Federal research and methodologies. The clients of Federal research are not just the Federal Government itself, or even State governments, but local governments. I hope that the State Cartographer's tasks can include communicating local needs to the Federal Government. Although there are only two State Cartographers, more may be established if the position proves to be an effective channel of communication.

Wickham (H. Dell Foster Co.): I would like to comment on Ziegler's statements that there is no automation at the State level and that automation is dependent on Federal assistance. Today there are automated systems not only at the State level, but at county and city levels. I can assure you also that there are technically capable people at all levels in some States.

Ziegler: I agree with you. I was speaking from the standpoint of my short term in Wisconsin. In certain areas of Wisconsin, like southeastern Wisconsin, planning commissions are involved in advanced systems, but generally such cases are rare. The areas that can afford automation have it. Since southeastern Wisconsin has 40 percent of the State's population, its tax base is higher than the northwestern section with 2 percent of the population. Yet northwestern Wisconsin probably has more significant problems.

Finnie (Private consultant): A number of the larger municipalities are involved in all kinds of mapping activities including acquiring automated digital data. What is going on at the Federal level, specifically in USGS, regarding common design criteria for special-purpose products or data that would be available to interested local governments and private contractors?

Southard: At USGS we are working in two areas. Since we're not very far along in either area, however, most of what I say is a promise rather than a statement of accomplishments. Some of you are aware of the two large-scale city mapping projects in Fort Wayne and Charleston, with followup projects scheduled in San Francisco and in Frederick, Md. These projects will furnish a badly needed data base from which these cities can properly digitize different kinds of information for solving many city problems. So far our work is experimental and leans heavily on studying the applications of these new products.

The other area of concern is intermediate-scale maps--1:50,000 scale and 1:100,000 scale in county format and 1:100,000 scale in quadrangle format for a quarter of a 1:250,000 map. We're using feature coding so that we can make digital displays at scales other than the basic data base scale of 1:100,000. These maps are being applied to energy resource development, in coal leasing areas under study by the Bureau of Land Management and in geothermal areas in southern California--ambitious projects of high interest.

# Professional Implications of Automation Panel

Joel Morrison, Presiding
University of Wisconsin

Albert W. Ward
Central Intelligence Agency

Edward P. Devine
National Ocean Survey

Morrison: The professional and educational events happening in cartography today are inevitable and would have occurred without automation, but automation has hastened these developments, making a revolution out of the cartographic evolution. Automation has changed almost every cartographic problem.

First, automation has relieved the cartographer of the time-consuming work of sitting at a drafting table. I'm not saying that using some automated equipment does not involve time-consuming work, but the cartographer now has more time to concentrate on what he is doing rather than on how he is doing it. As a result the cartographer can pay more attention to the design of cartographic products than ever before.

Second, the purpose of the map can be more specific. Maps made with a large investment of time have to be used for years. Now maps can be produced for more specific uses and less longevity. With automated equipment it is no longer necessary to print a map or even to have a hard copy map.

Since automation allows cartographers to spend more time designing special-purpose maps of less longevity, cartographers must carefully define map purpose. In other words perhaps the most important long-term effect of automation on professional cartography will be to hasten the development of a theoretical structure for the field. The structure is developing around the map as a communications medium. I will not say that without automation cartography would never have developed this theory, but automation has definitely advanced it. This theoretical structure gives cartography a completely scientific base, maybe for the first time in its history.

Previously the geodetic and projectional aspects of maps had a scientific base, while cartography was thought of as an art. Now cartographic art and technology are recognized as tools in a scientific field. The recognition of cartography as a science has caused a proliferation of professional cartographic societies and journals. Since 1961 at least five international journals were started, all are devoted to our field alone. The International Cartographic Association has been active only in the last 20 yr. Now undergraduate and graduate programs in cartography are available at colleges and universities, and there are positions with the title "cartographer." Although some people have distinguished between mapmakers and cartographers for many years, the distinction is now clearer than it has ever been. The cartographer who directs a mapmaker or a draftsman is a professional, and he must have a broad education to prepare him for this position.

The goal of educating the professional cartographer must be to create a generalist in one sense and a specialist in another. The cartographer must understand the computer and its peripheral equipment; he must be able to state clearly what he wants done in terms that a programer can understand. It would be useful for the cartographer to be a programer, but I doubt that all the requirements on his time would allow him to be a skilled programer. In most automated cartographic work, the cartographer himself is not the programer, but he directs the programer, who is a member of his support staff.

The cartographer must also know something about the perception of the map reader. If his aim is to communicate to map readers, then the cartographer must know how they will react to each option in the automated system.

A knowledge of statistical processing of data is also necessary in this day and age where we are flooded monthly with statistics from our Government and daily with statistics from news reports and papers. But because cartographic data generally require enhancement and/or generalization and because repeatable generalization schemes rely heavily on statistically processed data, the cartographer especially needs a basic understanding of statistical processing.

Finally, a professional cartographer must have some knowledge and ability in management and budget operations. He must be able to efficiently operate both equipment and personnel.

Ward: We are witnessing the most revolutionary cartographic development since the invention of the aerial camera. The effects of automation on mapmakers are enormous. I am not referring to the prospects for unemployment, which may or may not exist, but to the different tasks that cartographers will perform in the future. We know that automatic plotters will do the work of cartographic draftsmen. But what about the professional, the person who conceives the map? How will his life be affected?

Although design is basic to every map, the word design repels those who think of design as merely esthetic. If someone says that the London taxicab is a superbly designed vehicle, he does not mean that it is the most beautiful thing on four wheels, but that it is maneuverable, comfortable, safe, and durable. It's also rather ugly. I accept the premise that a map can be well-designed and ugly at the same time.

While the London taxicab design recognizes the needs of the users, cartographic designs reflect the tastes and prejudices of the designer. Cartographers seem to perpetuate archaic methods of portrayal. Are these methods adequate for today's customers whose association with graphic information is for the most part through television commercials? We must cater to the American people, and they have no patience with tedious maps. We must stop making maps for each other and start making maps that people will want to use. Automated methods will not only enable us to process data and to construct lines and symbols, but will also free us from the tedious parts of our jobs and allow us to spend more time designing appealing cartographic products.

In 1966 a landmark article entitled "Graphicacy Should Be the Fourth Ace in the Pack" appeared in The Cartographer. The writers contended that formal education stresses three aces--articulacy, numeracy, and literacy--but leaves out the fourth ace, graphicacy. If that fourth ace ever gains equal status in American education, perhaps we will become even more map conscious than our European friends.

We have an enormous challenge to shape our maps to public taste and to bend the public mind to understand the importance of comprehending spatial relationships. Automation will help us do a better job more cheaply and more quickly than we have in the past. In short, we can achieve volume production on a quality scale.

Cartography is in a stage comparable to the automobile industry in 1910. Motorcars of that day closely resembled the horse-drawn carriages that they replaced, sometimes even to having a whip socket on the dashboard. It took a Henry Ford to understand the needs of the mass market and a decade of design innovation to achieve a unique look. Maps produced in 1984 will probably be quite different from those produced today. Gradually we will rid ourselves of such archaic notions as north orientation, geographic grids, precise shorelines, and verbose legends and footnotes, and we will focus our attention on the spatial relationships of features important to man.

How do we achieve this goal? First we must experiment with design, and automation makes such experimentation possible. In my organization, we have a data bank and a plotting system. We can design alternative cartographic displays, produce and evaluate each, and then make a final decision on scale, size, content, and specification. Second, we can use the results of studies in visual perception. With a plotter we can generate a variety of symbol gradations within a few hours and make a test map for its gestalt effect, before choosing the final design. Third, we can stop designing maps for posterity. We can solve today's problems now and generate a whole new map for tomorrow's problems more cheaply than revising an existing map. Finally, professional cartographers will have to be imaginative. They will have to be in tune with user needs as never before, and they will have to understand the problems of visual perception. I will know that we have won the revolution when I ask my local sports-shop clerk for the Appalachian Trail Map, fall-colors version, and he says, "Do you want the normal vision edition or the bifocal edition?"

Devine: In 1972 the question at the 32d Annual Meeting of ASCM was whether automation would survive? Now the question is how fast can we automate? In 1972 I said that the new cartographer would be a crossbreed of the old cartographer and the computer scientist. I advised the cartographer to promptly study as much computer science as possible. Recognizing the fact that some of us have been in the field many years and are not about to go back to school if we can help it, we should try to learn as much as we can in order to communicate with the computer scientist. We must depend on him to do the programing because even though we might study programing, unless we do it every day, we won't retain the skill.

Two years ago I was involved in the Association for Computer Machinery, which was also concerned with educating the computer scientist. A task force was formed to develop a curriculum, headed by Professor Atchison (Univ. of Maryland). According to the resultant curriculum, prerequisites for courses computer graphics or information retrieval systems included an introduction to computing, programing, data structures, programing languages, and systems programing. Assuming that each course was 3 credit-hours, the cartographer would have to take 8 courses or 24 credit-hours, the equivalent of a master's degree in computer science, to be independent of the computer scientist. The courses required today are introduction to programing, FORTRAN for computations and projections, and COBOL for state structures, data banks, and computer graphics.

At the same time we have the opposite side of the coin. Computer science has entered the field of cartography, and I welcome all the computer scientists into the field. But they should learn about cartography so that they can communicate with cartographers just as cartographers are learning to communicate with them.

When Professor Campbell, Chairman of the Geography Department at George Washington University, was asked to establish a course of study for a Bachelor of Arts in Cartography, he organized a team that consulted various government agencies and private industries for requirements. They decided on 189 absolutely necessary credit-hours which had to be condensed into a 4-yr course of 120 credit-hours. Courses include photogrammetry, geodesy, geomorphology, projections, map construction, map compilation, and map reproduction. Through such courses the computer scientist could also become familiar with cartography. When the cartographer and the computer scientist become one person, we will have the new cartographer. And the communication problem will disappear because he can have a chat with himself without any problems.

<u>Cuff (Temple Univ.)</u>: I agree with the concern for design, but I am not really sure how automation is encouraging this concern or improving design. The very process of learning about automation distracts some designers from design. I hope that this distraction is just temporary. Also, installing and experimenting with a new system takes time, and sometimes we become so enamored with the system that we are completely sidetracked from design work.

Some computer-aided techniques are used when they are neither appropriate nor design-effective. For instance, some atlases are not designed to convey certain themes effectively, but to use a technique just because it exists; these atlases are really a collection of SYMAPS. A similar technique, frequently used but not ideal, is SYMVU. This technique is fine for smooth surfaces, but the three-dimensional choropleth map is done more effectively by hand, although the process is slower; production time, however, depends on the individual. Would you elaborate on how automation is improving design?

<u>Morrison</u>: What you say is true in the short run, but in the long run automation will affect design. In Ward's shop they do not make final design decisions until they have studied 3 or 4 possibilities. When you make maps manually, as we have for so many years, you must have a final design from the beginning. Ward is saying that with automation he can carry three designs almost to completion before making his final decision. This ability gives great flexibility. Granted, in the transition to automated techniques, it can be frustrating for organizations with limited automated facilities and trained personnel.

<u>Ward</u>: In a production shop, after a map is made, it has a shelf life of a week to 20 yr. When the map comes up for revision, it is almost never thrown away, regardless of how good or bad it is, because it is cheaper to revise it. With automation, however, it can be cheaper to make a new map than to make corrections. Thus you can constantly work on innovations and improvements and keep the map in tune with the times.

<u>Thompson (U.S. Geological Survey)</u>: The real issue is not how automation

can improve map design, but how map design will accommodate automation. For example, if an automated system can produce contour lines, but not numbers, then numbers can be omitted at least in the first compilation. We need to be flexible in our current standards and designs so that we can make such changes and so that automation techniques will be easily compatible with our final product.

Morrison: We haven't really designed our maps today to fit the machines that are producing them. We are designing the machines to do what we have been doing manually. Therefore we are not taking full advantage of the possibilities of progressing in our field.

Rhind (Univ. of Durham): As someone involved in education, I am well aware of the grave difficulties of balancing oneself between revolution and reaction. Not only are we automating existing products, but we are thinking about how maps are made in the same way that we did in the past. For example, one can argue that the term "map projection" is redundant now. "Map projection" is an example of one type of spatial transformation; rectification of sheets to make sure that they are square is yet another type of map projection, and interpolation to contour surfaces might be another. In essence, we must acquire a different concept of the subject, but we won't get it overnight. However, we must think in new terms rather than taking a clay brick out of cartography and replacing it with a plastic one.

Finnie (Private consultant): With all the expenditures for automated equipment, we are still spending 80 percent of our mapping resources for people. There are many different concepts of training, organization, and utilization of people in the various organizations of the U.S. However, the majority of the mapmakers are professionals. The Defense Mapping Agency Aeronautical Center in St. Louis--probably the largest single map/chart organization in the U.S., with almost 4,000 people--has about 2,000 professionals, people with bachelor's degrees and often advanced degrees. Considering the kinds of systems that they operate ($250,000 to $1-million computer-driven systems), it is probably advantageous that they are well-educated. Most scientific computer operations, including special purpose operations, in that same organization are performed by cartographers who were hired as cartographers and then retrained as computer scientists. ACSM and other organizations should spend more time studying the use and development of these resources that represent 80 percent of mapping cost.

Bie (Soil Survey Institute): The systematic, general-purpose geologic and soil maps of the last 100 yr have rather limited use for the more intensive purposes for which maps are now requested. One result of automated cartography has been the invention of two very expensive methods, line-following and scanning. With the ability to make special-purpose maps by computer, soil scientists and geologists in many countries have re-evaluated their methods of collection. They are moving away from the fuzzy human algorithms used in the field for delineating different mapping units, toward point data and mathematical interpolation algorithms linked with automated cartography.

Moellering (Ohio State Univ.): Usually people use maps to analyze a spatial problem. With automated cartographic techniques, it is easier to digitize displays. Automation has also affected geographic analyses and data bases. We should bring these two together so that when we study a problem we will have an analysis of the geographic data and a cartographic display.

Morrison: The Special-Interest Group in Graphics of the Association for Computing Machinery is sponsoring a second symposium on computer graphics and interactive techniques this summer (1975) that will include a session on cartography.

## Operating Systems Panel

Joseph Diello, Presiding
Rome Air Development Center

Hans-Jorg Gottschalk
Institute for Applied Geodesy
Federal Republic of Germany

T. Allen Porter
Department of Energy, Mines, and
Resources, Canada

Robert Sinclair
Defense Mapping Agency
Hydrographic Center

Henry Cook
Defense Mapping Agency
Topographic Center

John V. Sharp
Defense Mapping Agency
Topographic Center

Diello: Almost everything that the people on this panel have to say has been said before, and in most cases it has been published. However, I have asked each person to briefly describe his system in order to refresh your memory and perhaps enable you to challenge their present endeavors.

Gottschalk: We spent more time getting the money for our system than getting the system assembled. In November 1974 we got our system, which is now located at the Institute for Applied Geodesy in Frankfurt. The hardware consists of: the center processor, a PDP-1145 computer with 80-k 16-bit word memory; 4 disk packages of 76-million-bit storage capacity; 2 9-track and 800 BPI magnetic tapes; a paper tape reader capable of 300 characters/sec; a paper tape punch capable of 75 characters/sec; a card reader capable of 300 cards/min; a Contraves Coragraph drawing machine with light-spot drawing and scribing and tangential control; a Bendix interactive digitizer called Cordimat; an interactive graphic display; a Tektronix 4014 or 4015 with a hard-copy unit and a graphic tablet; an 80-characters/line printer; and a teletype console. The system can be connected to a large-scale computer for precise teleprocessing. The cartographic software runs under the operating system RSXIID for the PDP-1145, which allows multiprograming and real time processing. Most of the programs are written in FORTRAN IV, but some are written in PL/1 assembler.

A cartographic system performs three major functions: digitizing, editing, and drawing. Batch processing of other programs is done in the background. The heart of the system is the cartographic data bank which allows storage and retrieval of cartographic data.

For digitizing, there are two possibilities, on-line and off-line. With on-line digitizing, the data and the digitizing progress are displayed on the storage tube and make it possible to edit the data. With off-line digitizing, the data are directly stored sequentially on magnetic tape.

The following procedures are performed on-line: The points (up to 25) where the graphic information is registered and the digitized data are transformed into a geodetic system, for example the UTM. We always use a plane-coordinate system, not a geographic one. Using a menu and a keyboard, we digitize the lines with a cursor. There are facilities for point digitizing and stream digitizing, and we have the capability of storing about 450 points on the disk in one session. We can input up to 4 headers per subject, and we can define for one session about 63 different headers when we are digitizing. The digitized subjects are displayed during the digitizing process for easy monitoring. Editing at this stage includes deletion of digitized subjects, insertion of new subjects, probability checks, rejection of erroneous data, and output of data in three different formats. For off-line digitizing, the digitized data are output directly on magnetic tape. (Only a few error codes are possible in off-line digitizing.) The data are then processed with a batch program.

Numerous editing functions are contained in the system. For output and data searches, the functions are windowing and identifying points, line elements, and sections of line elements. For manipulation of data, headers may be checked and points, lines, and parts of lines may be deleted, moved, connected, or replaced. Manipulated data are stored by means of additional statements.

For drawing, data are extracted from the data bank and filtered because the drawing machine uses high-order interpolation. Symbolization is automatically selected from a table in accordance with a scale and the kind of map. We make tables for several scales processed on the system--1:50,000, 1:200,000, 1:250,000, and 1:500,000--which are correlated with the disks where the symbols are on the photohead. There are two different tables for photoscribing and for scribing coated foils.

The data bank consists mainly of three sets of data. The data bank description gives the necessary information about the data to be stored and the structure of the data. An edge-description data set contains descriptions of line elements and points stored in the bank, that is, mainly headers. The stream data set contains coordinate strings of the elements. Edge descriptions and strings are connected by pointers. In addition there are two inverted files, a location index and a header index, which allow retrieval of the data. With this system we have compromised between storing data in a chain structure or a grid structure.

All the tasks--digitizing, editing, and drawing--are performed simultaneously. Other tasks with less priority are run in the background. This system will be used by persons and institutions in the Federal Republic of Germany interested in producing maps at scales of 1:5,000 to 1:1,000,000. Our goal is to discover methods for accelerating mapmaking in Germany. We designed this system mainly as a tool for research.

Porter: The Department of Energy, Mines, and Resources in Ottawa, Canada, has an on-line system for collecting, manipulating, storing, retrieving, and presenting cartographic data. This system consists of: 2 computers--a PDP-11 concerned with cartographic peripherals which is on-line to a PDP-10; 5 digitizing stations on-line to a PDP-11; a flatbed plotter also on-line to this PDP-11; and a remote station interfaced to the PDP-11 with a digitizer and a PDP-11 at this remote station.

In 1970 we began acquiring this equipment and developing an automated cartographic facility. We had to write software for the computers, build some equipment interfaces in-house, and develop procedures for using this tool. The system was first used in the production of 1:50,000-scale topographic maps with the idea that once satisfactorily operable, extensions of this system could produce small-scale maps, aeronautical charts, geologic maps, and other products. We also planned to have stereoplotters on-line to the system to enable direct capture of topographic data.

In the data collection, points or lines are digitized with a resolution of about 0.001 in. The operator first types a feature code and then tracks with the cursor to the end of the feature. The source material is usually a deep etch of the lines which allows the operator to track effectively using a cursor with a stylus that sits inside the edge; tracking is more accurate and 4 times faster than without this edge. A sign-on procedure enables the user to relate the cartographic table coordinates to a particular grid (usually UTM). The operator identifies the current position of the manuscript on the digitizer with respect to the grid, and the data are transformed by rotation and translation to a line with previous data.

Because digitizing is on-line, the operator carries on a dialog with the computer and can edit as he digitizes. The operator sets a scan rate, usually 50 scans/sec. The PDP-11 scans the output from that digitizing station, but sends the data to the PDP-10 only when there has been a change from the last scan. The PDP-10 standardizes the data and poses a 0.0001-in separation on successive points on continuous lines. Thus, on-line digitizing has two features--immediate computer response to the user and some data reduction and filtering as data are collected. The data are finally sorted and then archived either on disks or on tape.

We have a 48-in by 60-in flatbed plotter which also has a resolution of 0.001 in. We use it with a ball-point pen to get a preliminary plot of the digitized work. This plot is used for subsequent editing. Once map editing is completed, the plotter is used with scribing and cutting tools to prepare the various color plates for printing and the open-window negatives, such as blue water or green forest. Feature codes allow the computer to select the relevant features for each plate. Plotting routines have been written for symbolization appropriate to topographic mapping--dashed lines, houses, or railways.

This system was developed in-house; a small group wrote the software for digitizing, organizing, and plotting the data and for the PDP-11 operating system. This group is now writing the next level of operating software, which will be better than the present level and should give more flexibility.

Since we have been in production for about 2 yr, we are experienced with this system. The digitizer and plotter operators are cartographic draftsmen who were trained to use this equipment; in fact, they have helped develop procedures to make this system a good one. Two outside consultants have also contributed to the development. In 2 yr we have digitized about 140 1:50,000-scale topographic maps, some experimental maps of different scales and projections, and some geologic maps. In 1974 we finished 75 topographic maps, and we have another 40 as well as 3 geologic maps in production. We hope to increase productivity after the current phase of development because we are still only in a one-shift phase. We have to use the remaining time to develop the next level of software and to give people a chance to work with the system. After this current phase of development, we hope to provide cartographers with a more flexible and more powerful cartographic facility.

Sinclair: I am standing in for Dan Dixon to tell you about production use of the Lineal Input System (LIS) previously described by Moritz and Dixon. First, I will refresh you on the LIS configuration. LIS, which is part of a larger Advanced Cartographic System (fig. 1), is a device for acquiring data from analog sources in order to form a data bank. The data derived from the bank will be used to produce compilations or digital products. Until we have a data bank and a digital compilation device, we are using application programs specially written for these purposes. The primary purpose of LIS is to produce error-free digital data for the bank (fig. 2).

LIS consists of three hardware subsystems and a comprehensive software system that integrates the subsystems into one functional unit (fig. 3). The system is controlled by the master processor, a PDP-15 which supplies the work stations with program modules for execution on the minicomputer or on the display. In figure 4 the master processor is next to the operator, and the mass storage is behind him. The control is a PDP-15 with two 262-k-word fixed disks, two 10.2-megaword disk pack drives, magnetic tapes, and the normal peripherals. The proof plotter is a Xynetics plotter with a Hewlett-Packard minicomputer used for producing proofs of data files generated by the system. The main part of LIS is the work station, which consists of a Gradicon digitizing table, an Imlac PDS-1 minicomputer, and the appropriate display and keyboards. The whole operation centers around getting the necessary programs to the work station and filing the data produced. Figure 5 is a schematic of the work station, and figure 6 shows what that work station looks like in operation. All display, data entry, digitization, and editing routines are transmitted from the master processor to the work station and stored there. Conducting all cartographic operations from the work station eliminates delays incurred by time-sharing the master processor and allows parallel processing.

This tree (fig. 7) indicates the type of software used by the system. An executive monitor, derived from the RSX supplied by DEC, ties everything together. Terminal support software is necessary to use the work station on-line. The data management package sorts the data generated by the digitizers into proper files for later retrieval and use. The batch programs, subdivided into input and output processsing, allow many operations to be conducted against the working file. The system programs module is very important to the personnel responsible for maintaining the system software.

The operation of LIS is based on a man-machine dialog whereby all of the necessary cartographic functions--digitizing, editing, and drawing--can be accomplished. The cartographer is presented with a series of operations which, if he takes them sequentially, will result in a complete data file ready for chart production. Using the batch software he can create a data file for later use, which is nothing more than a bookkeeping stage. A least-squares adjustment procedure built into the system allows him to register source material to the table and to the real world. The cartographer is then ready for on-line digitization. He can identify features with a rather complex data hierarchy set up to uniquely identify each feature on the entire source. He can record in the trace, point-point, or point-feature mode, and he can do a type-one edit with a digital eraser which allows him to correct the last 2 cm of his work.

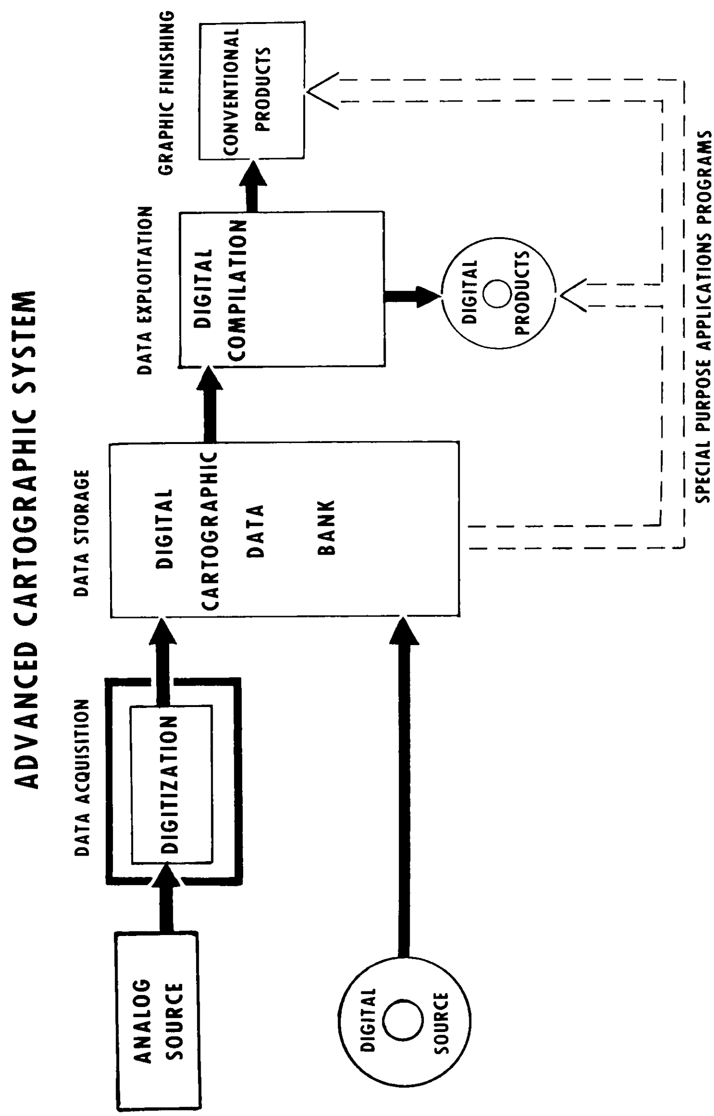

ADVANCED CARTOGRAPHIC SYSTEM
DATA ACQUISITION
DATA STORAGE
DATA EXPLOITATION
GRAPHIC FINISHING
ANALOG SOURCE
DIGITIZATION
DIGITAL SOURCE
DIGITAL CARTOGRAPHIC DATA BANK
DIGITAL COMPILATION
DIGITAL PRODUCTS
CONVENTIONAL PRODUCTS
SPECIAL PURPOSE APPLICATIONS PROGRAMS

Figure 1

# LINEAL INPUT DIGITIZING SYSTEM

PRIMARY PURPOSE: BUILD DATACELLS

THIS REQUIRES TAKING DATA FROM SEVERAL GRAPHICS EACH OF WHICH CAN BE AT A DIFFERENT SCALE, DATUM, AND MAP PROJECTION AND TRANSFORMING ALL THE DATA TO A COMMON FORM AND REFERENCE DATUM.

Figure 2

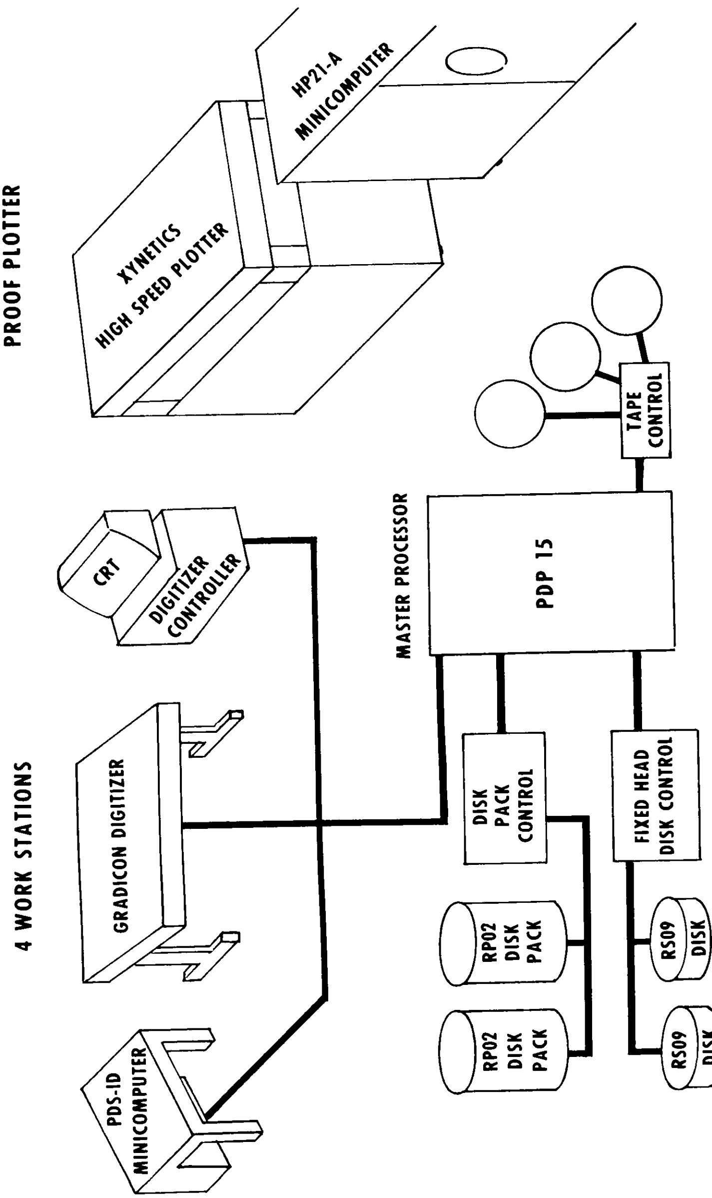

PROOF PLOTTER
XYNETICS
HIGH SPEED PLOTTER
HP21-A
MINICOMPUTER
4 WORK STATIONS
CRT
DIGITIZER
CONTROLLER
GRADICON DIGITIZER
PDS-ID
MINICOMPUTER
MASTER PROCESSOR
PDP 15
TAPE
CONTROL
DISK
PACK
CONTROL
FIXED HEAD
DISK CONTROL
RP02
DISK
PACK
RP02
DISK
PACK
RS09
DISK
RS09
DISK

Figure 3

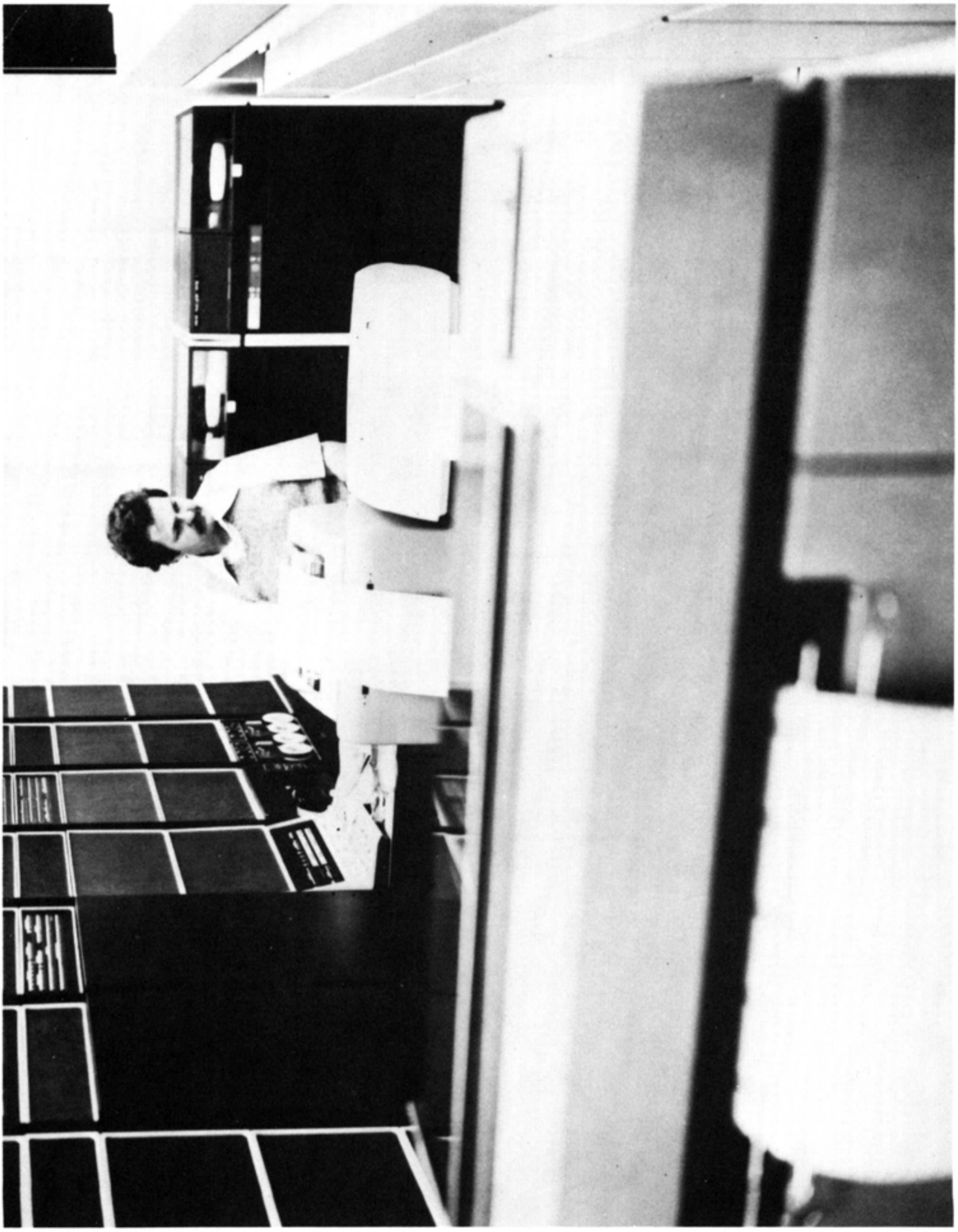


Figure 4

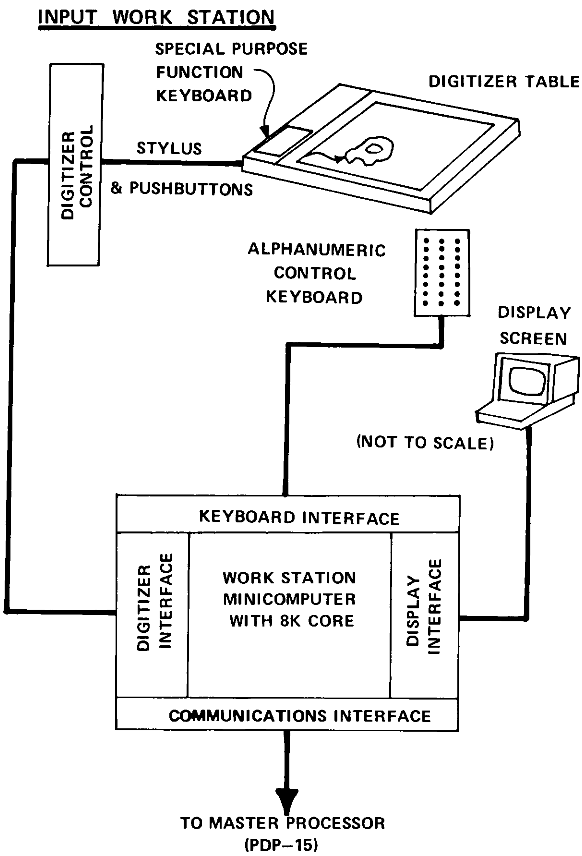

INPUT WORK STATION
SPECIAL PURPOSE
FUNCTION
KEYBOARD
DIGITIZER TABLE
DIGITIZER
CONTROL
STYLUS
& PUSHBUTTONS
ALPHANUMERIC
CONTROL
KEYBOARD
DISPLAY
SCREEN
(NOT TO SCALE)
KEYBOARD INTERFACE
DIGITIZER
INTERFACE
WORK STATION
MINICOMPUTER
WITH 8K CORE
DISPLAY
INTERFACE
COMMUNICATIONS INTERFACE
TO MASTER PROCESSOR
(PDP-15)

Figure 5

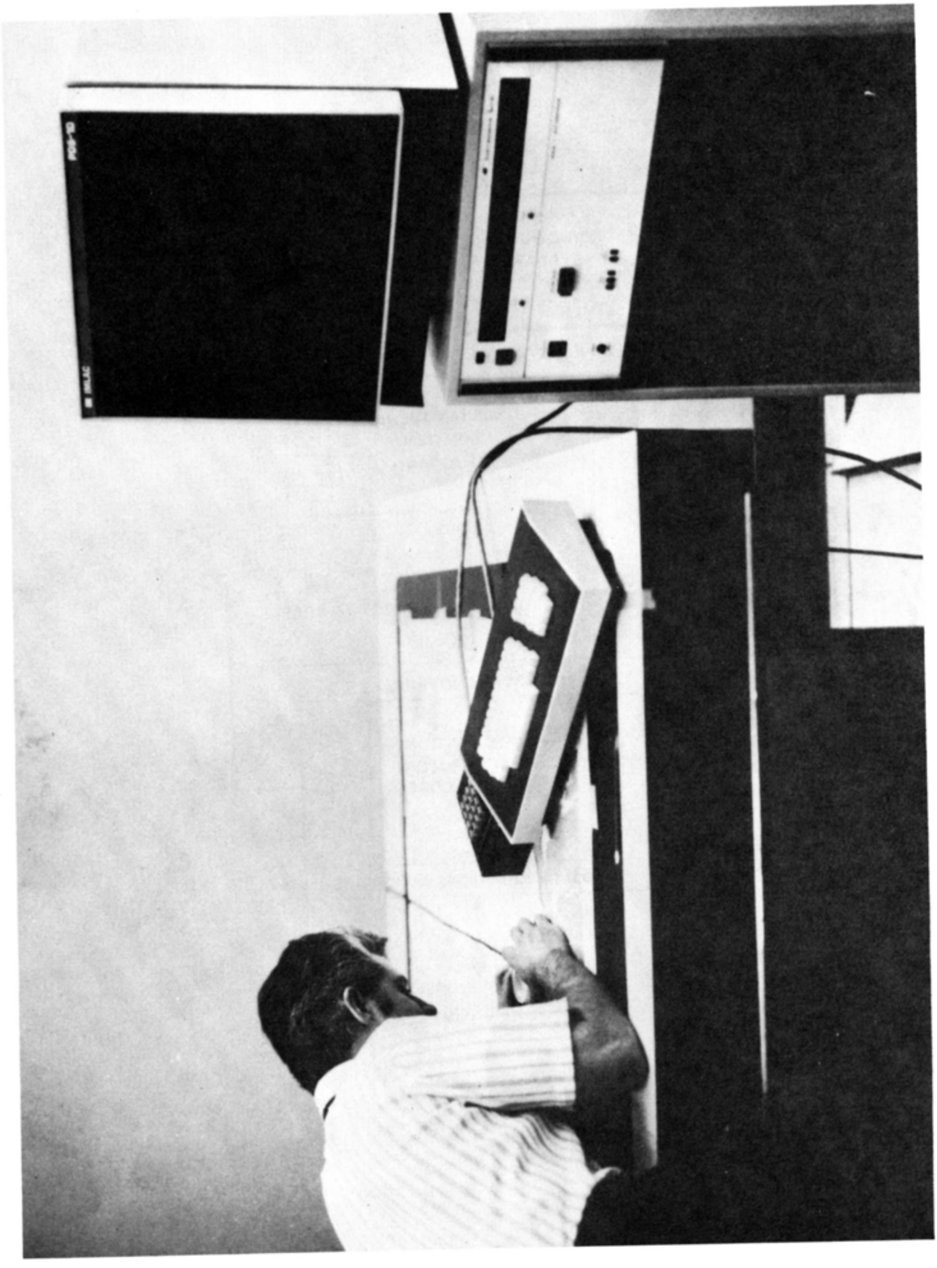


Figure 6

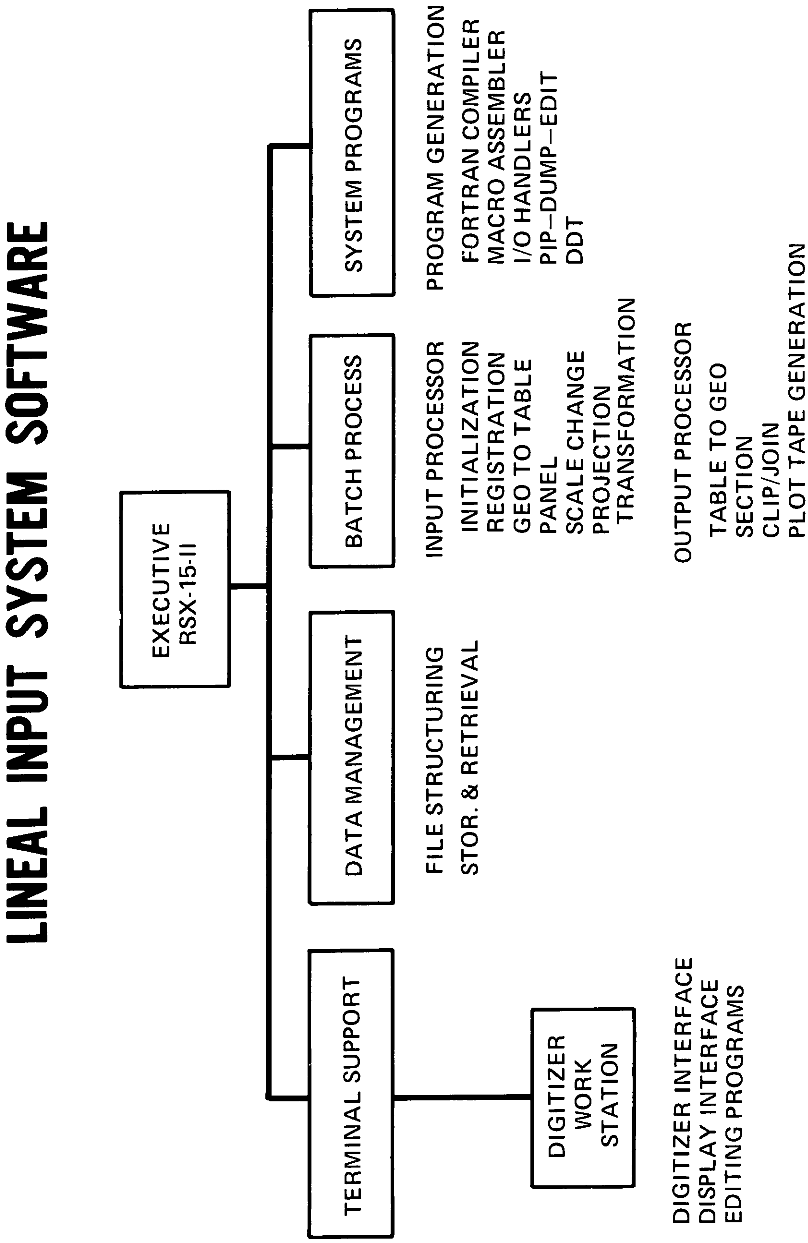

LINEAL INPUT SYSTEM SOFTWARE
EXECUTIVE
RSX-15-II
TERMINAL SUPPORT
DATA MANAGEMENT
BATCH PROCESS
SYSTEM PROGRAMS
DIGITIZER
WORK
STATION
DIGITIZER INTERFACE
DISPLAY INTERFACE
EDITING PROGRAMS
FILE STRUCTURING
STOR. & RETRIEVAL
INPUT PROCESSOR
INITIALIZATION
REGISTRATION
GEO TO TABLE
PANEL
SCALE CHANGE
PROJECTION
TRANSFORMATION
OUTPUT PROCESSOR
TABLE TO GEO
SECTION
CLIP/JOIN
PLOT TAPE GENERATION
PROGRAM GENERATION
FORTRAN COMPILER
MACRO ASSEMBLER
I/O HANDLERS
PIP—DUMP—EDIT
DDT

Figure 7

If this edit is not sufficient, LIS has a complete editing capability independent of the digitization process. The feature to be edited can be found with a "find feature." The feature may be called from the data file merely by placing the stylus over the feature and pushing a button on the cursor. The system will respond by displaying a header. If this header is correct, the cartographer accepts the feature, and a picture of the last 10 cm will be displayed on the Imlac screen. If he wants to modify the feature, he can modify the mid-segment or the end segment. He can join two features, delete features, or modify their headers.

Once a data file is complete and ready for further processing, additional batch programs are called from the work station. These processes allow the entire feature file to be converted to geographic coordinates instead of table coordinates, to be sectioned (sort of digital scissors), and to be paneled with other files to create one large file. The operator can also make scale and projection changes from the work station. At any time during production the cartographer may call for a proof plot. He may then edit, continue digitization, or call batch modes. The final product is a data file that may be used as a finished product or converted to an analog product at a new scale or projection.

Cook: The Semi-Automated Cartographic System at the Defense Mapping Agency Topographic Center (DMATC) has been in production since April 1974. At first glance, the system (fig. 1) may seem complex, but it is really not difficult to follow. Across the top of the figure are the collection devices, and in the center are the software support systems. DMATC data collection systems include the Digital Topographic Data Collection System (DTDCS), Universal Automatic Map Compilation Equipment System (UNAMACE), Symbols, Names, and Placement System (SNAPS), and cartographic and names digitizer systems.

Figure 2 shows our oldest system, DTDCS, which has a resolution of 10 mil. It has 5 digitizing stations on-line with the CDC-1700 computer. In the background is a disk storage and on-line plotter, for digitizing line vectors (specifically contour information) so that surface matrices can be extracted. UNAMACE (fig. 3) generates the orthophotograph, which is taken to the graphic digitizers, and the surface matrix.

Both DTDCS and UNAMACE generate a surface matrix (fig. 4); if a grid is laid across the surface of the Earth, there is an elevation at each grid intersection. Once the data are in this form, several products can be generated. For example, a three-dimensional hard copy (fig. 5) can be made by using a milling machine and high-density urethane to represent the topology; this is an old technique of DMATC for producing plastic relief maps. The elevation matrix can be input into the contour program to generate contours (fig. 6). The area outlined is an adverse area, where the stereocompilation equipment loses correlation and generates erroneous elevation data. This particular set of line vectors is taken back to the digitizers, the adverse area boundaries are defined, and the adverse data are suppressed by software. The surface matrix can be used to generate a slope map (fig. 7) for highway planning.

Figure 8 shows DMATC's present digital coverage--most of the U.S. This information, stored on about 1,600 tapes, has been compiled at 1:250,000 scale. Any questions or requests for these data should be addressed to the U.S. Geological Survey. (If you find anomalies in these data, please notify DMATC.)

With SNAPS (fig. 9), the lithographic copy is placed on drum locators,

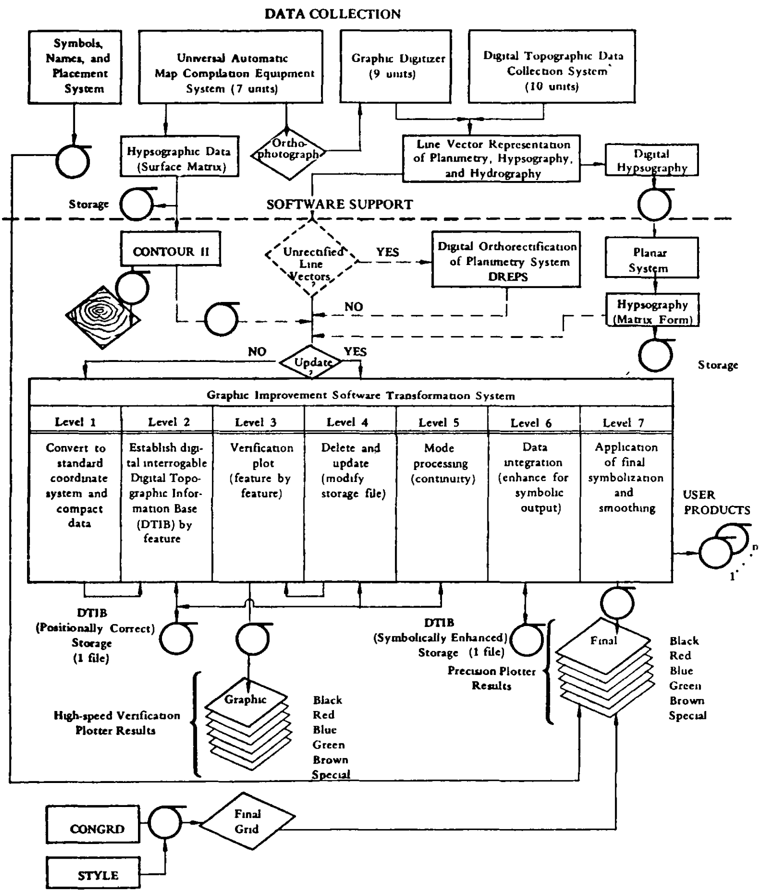



Figure 1.--Semi-Automated Cartographic System (SACARTS).

Figure 2.--Digital Topographic Data Collection System (DTDCS).

Figure 3.--Universal Automatic Map Compilation Equipment (UNAMACE).

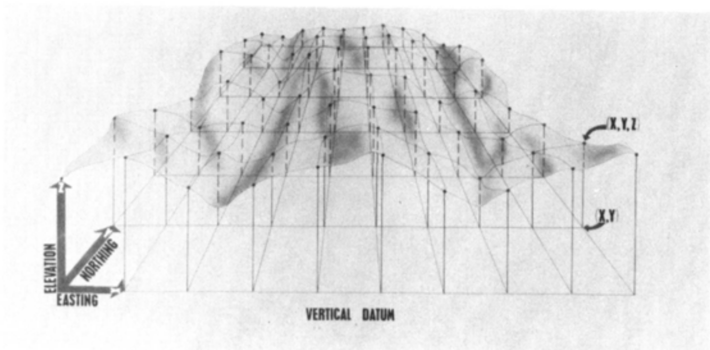



Figure 4.--Surface matrix (digital terrain elevation data).

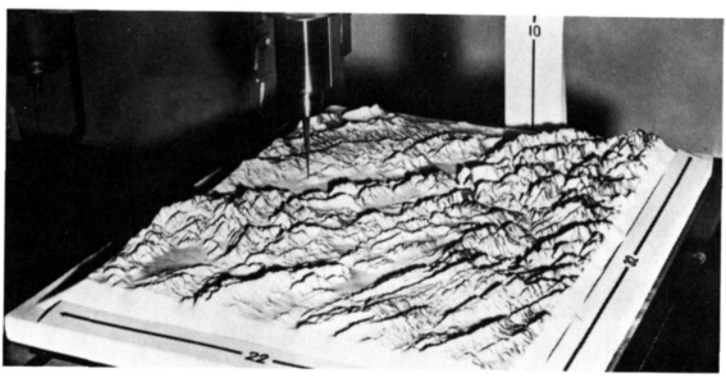



Figure 5.--3D portrayal.

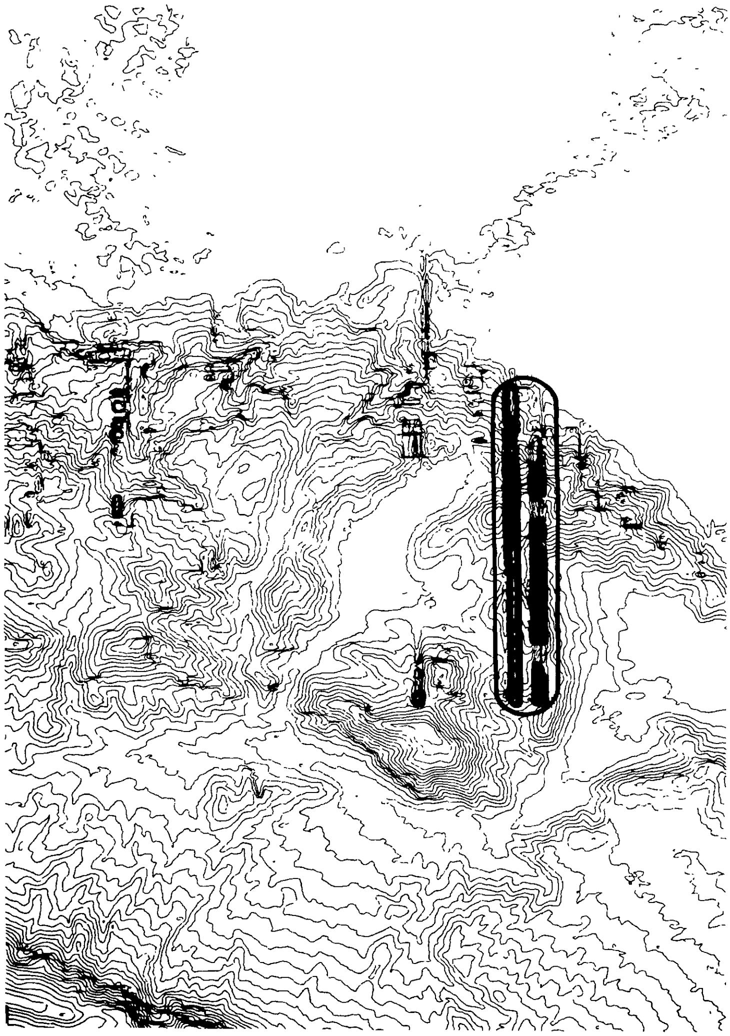


Figure 6.--Unedited computer-generated contours.

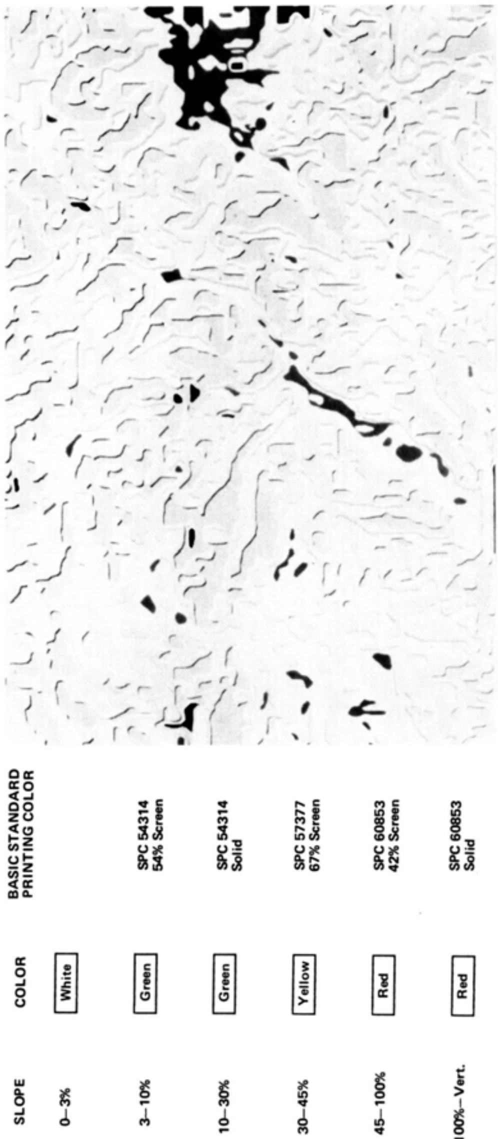



Figure 7.--Computer-generated slope map.

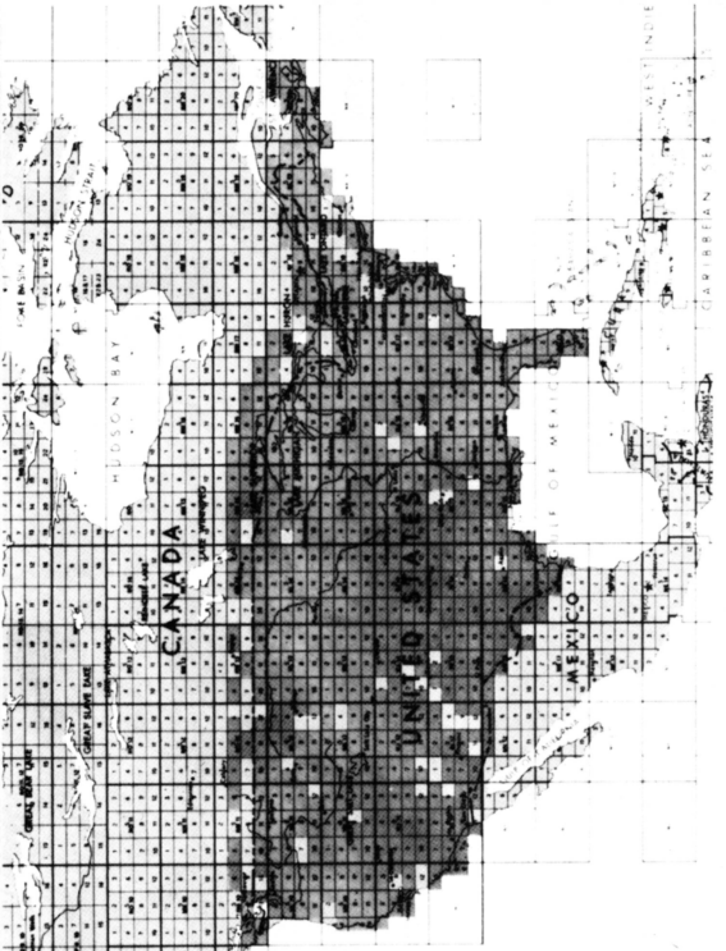



Figure 8.--Index of digital elevation coverage of the conterminous U.S.

and the operator digitizes the position and orientation of the names. The names are entered on the keyboard, and their coordinates are entered on the drum locator. This information, recorded by the computer, is then taken to the Photon system where the names are output onto 70-mm film. In conjunction with our high-precision plotter, the names are placed in their respective orientation to produce the finished names product.

Figure 10 shows newer graphic digitizers, familiar to most people. DMATC has several versions, but they basically consist of minicomputers, teletypes, and digitizing tables with 1-mil resolution. Operators may work either from compilations or orthophotographs. All of DMATC's systems are off-line in the sense that they are not tied to a large general-purpose computer.

DMATC's newest compilation equipment, the Digital Planimetric Compiler (fig. 11), was designed by the U.S. Army Engineer Topographic Laboratories. Five systems are on-line with the minicomputer.

The primary data manipulation system at DMATC is the Graphic Improvement Software Transformation System (GISTS). Other systems are the Planar Interpretation System, the Digital Orthorectification of Planimetry System, and the Automated Contouring System. The GISTS package (fig. 12) is the glue that holds the information together. The off-line digitizers generate generate magnetic tapes, which are then moved to the UNIVAC-1108 where the master files are built. These files are the data bases in interrogatable form (Levels 1 and 2). Once the interrogatable data base is built, information can be swept out using the general plot package (Level 3) that gives center-line information which can be ported out to the high-speed plotters for verification. Then, using light-tables, the operator notes the ambiguities or the areas of information that have not been put into the data bank and returns to the digitizer to generate the updates.

The add and delete function (Level 4) is performed in conjunction with the digitizer where an update tape is generated and returned to the U-1108. After Level 4, all processing is automatic. "Dirty" data do not have cartographic quality. Mode processing (Level 5) moves through each feature, trims, makes connections, and notes the intersections. This file is retained because it gives correct information.

Data are then moved into Level 6 for data integration. Considering each feature on a single plane, the processor inspects these planes for any conflicting data. If there are problems, the processor goes to its hierarchy tables and begins moving or displaying information for symbolic purposes only. This operation is accomplished for graphic output, and a graphically enhanced file is generated.

Once that operation is completed the symbolic output (Level 7) is applied to the Level 6 retention file. Level 7 maintains all references for each feature in the file and asks certain fundamental questions: "What is the symbolic requirement for this feature: Is it a dash line or a solid line of a particular width? What is the best plotter technology that the data can be ported out to?"

The GISTS philosophy is "fail-soft" (fig. 13)--the system is designed so that no single change in technology will affect the system. It is input independent--it can be given any digitizer desired. A translation module can be written so that the digitizer can be interfaced to the software. It is also output independent. DMATC can redefine the symbolic directories of Level 7 to accommodate the latest technology in high-speed

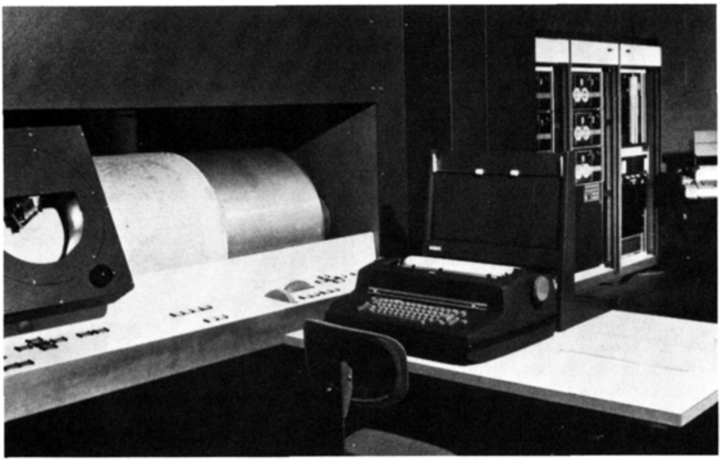


Figure 9.--Symbols, Names, and Placement System (SNAPS).

Figure 10.--Graphic digitizer and closeup of digitizer position.

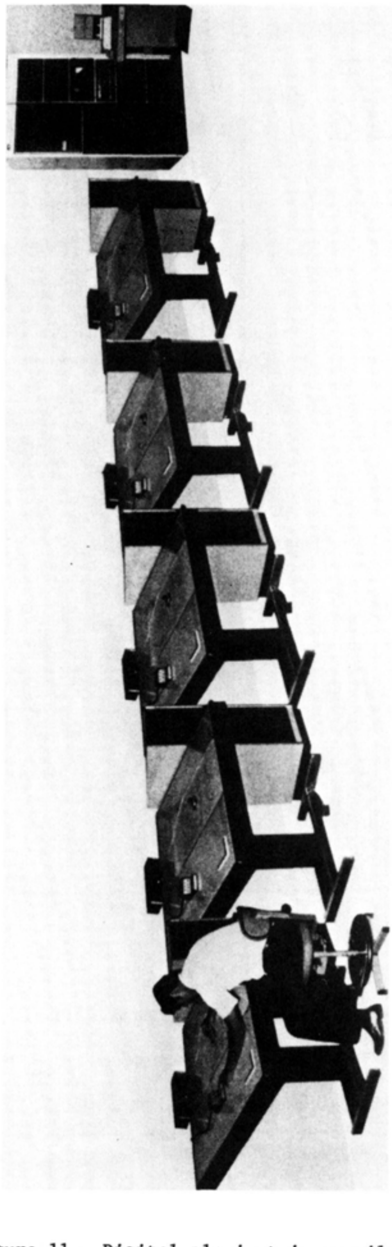


Figure 11.--Digital planimetric compiler.

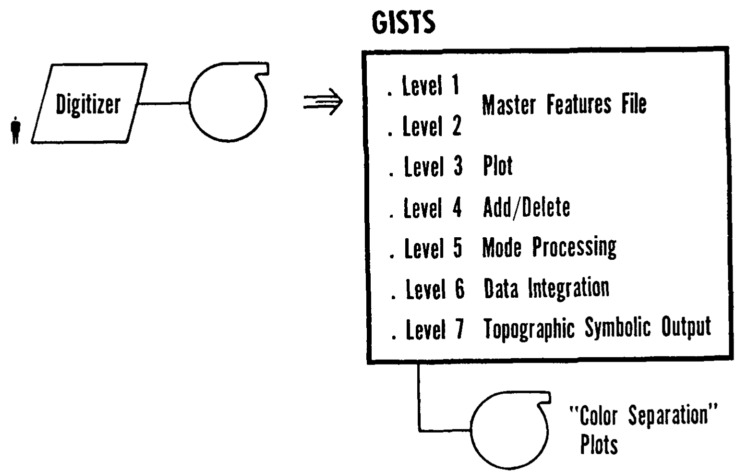



Figure 12.--Conceptual overview of GISTS.

- Input Independent
- Output Independent
- System Modular in Architecture, Redefinable Under Parameter Control
- "Universally Accepted Programming Language". . . FORTRAN IV
- Computer Independent (Redundancies in Data Structure)

Figure 13.--System philosophy--fail soft.


Figure 14.--Xynetics plotter.

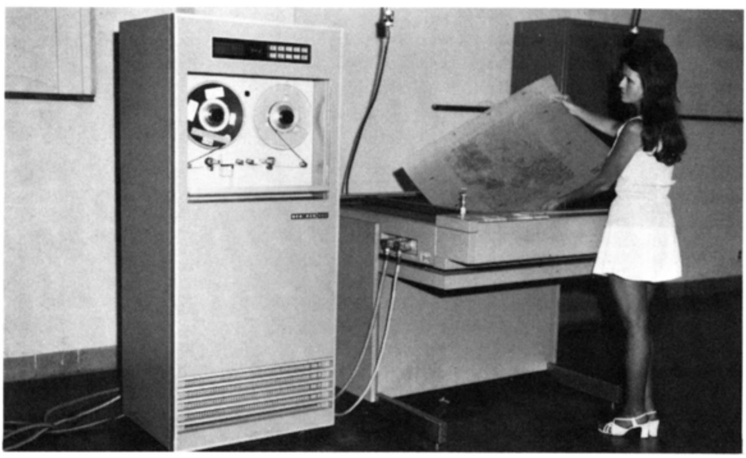


Figure 15.--CalComp plotter.

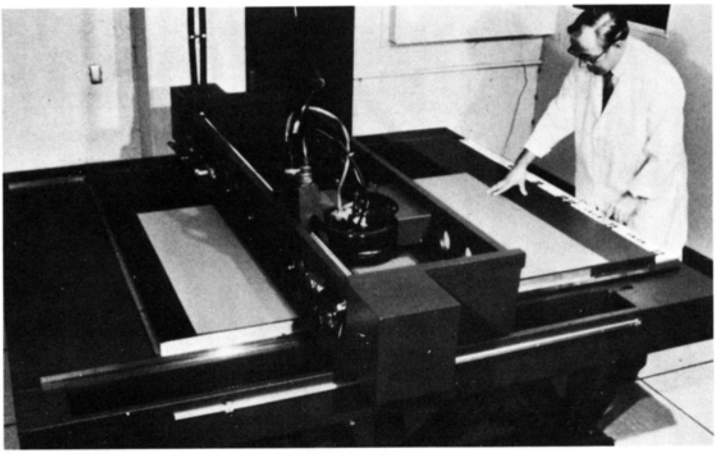


Figure 16.--Concord plotter.

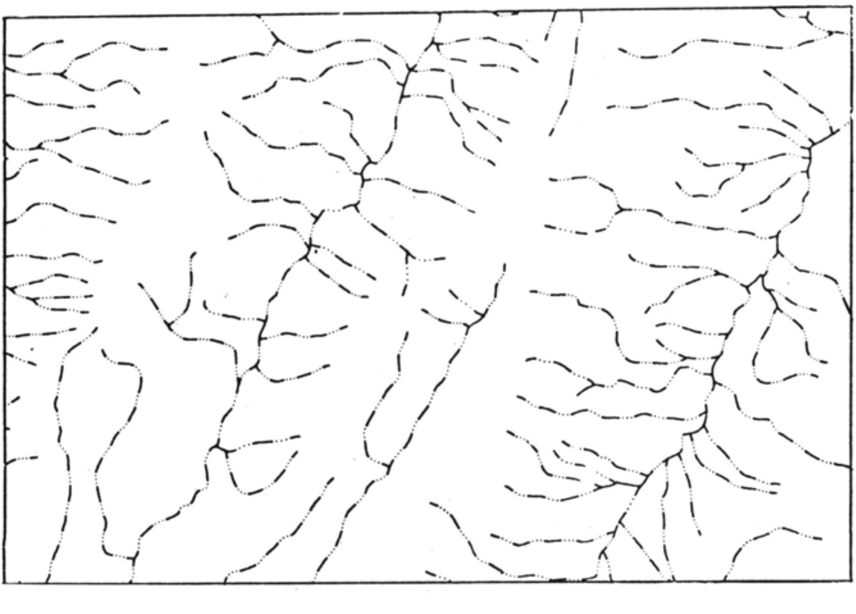


Figure 17.--Reproduction quality plots from GISTS.

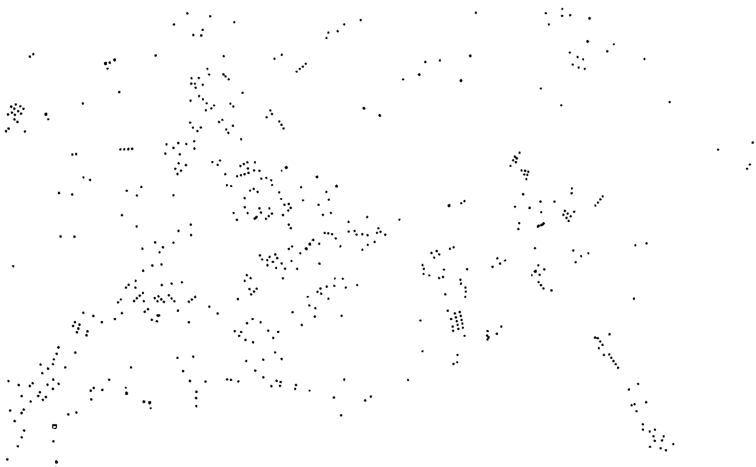


Figure 18.--Sample plot of black point symbolization.

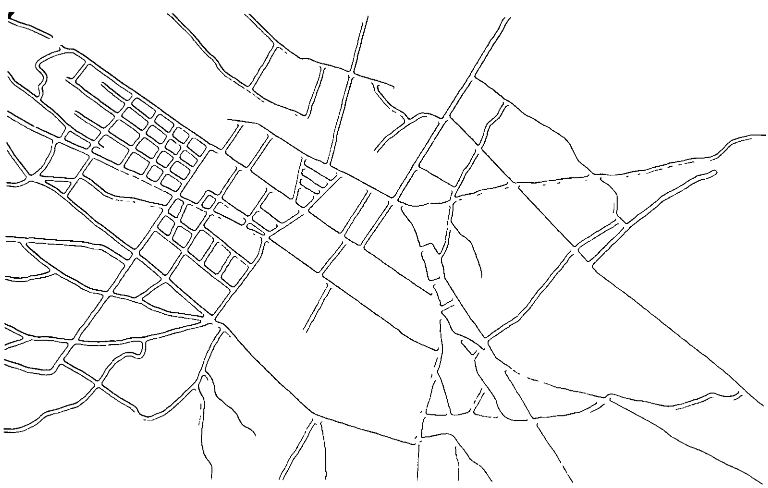


Figure 19.--Road casings generated by the photographic process.

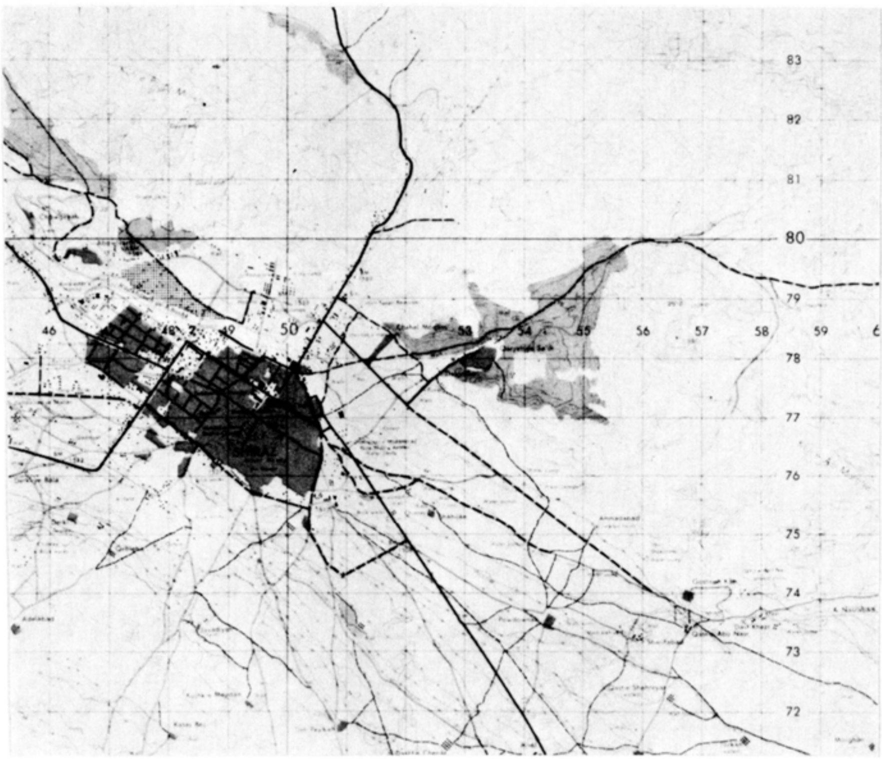



Figure 20.--Digital map (Shiraz).

plotters. The system is modular and redefinable under parameter control. The mesh interval is 2 mil, but it can be redefined as DMATC's mission requires. The program is written in FORTRAN IV in an attempt to be as universal as possible. These data have been made as independent as possible. Redundancies have been programed in the data structures so that we can move from a UNIVAC, a 36-bit word machine, to an IBM, a 32-bit word machine, without adverse effect on the data files.

The Xynetics plotter (fig. 14) is the high-speed plotter that DMATC has just put into production. Figure 15 shows the old CalComp plotter which is slow in comparison to the Xynetics; DMATC does not have one of the newer CalComp plotters. The precision plotter (fig. 16), which can either scribe or photoscribe, has a 60- by 60-in bed surface.

The following items can be produced from Level 7. Figure 17 shows a drainage network in which each of the intersections start and terminate in solid lines. Level 7 takes care of all of these peculiarities in the data nets. They are symbolized exactly to specifications. At Level 6 if a building is on top of a road, the processor will displace it and orient it in the direction of the road. Since the buildings are square (fig. 18), they have a definite angle. Figure 19 shows a road network prepared completely by software or semiautomatic processing. The network is drawn twice at varying lineweights, and one is used for a photographic mask.

Figure 20 shows the Shiraz sheet that was distributed here this week. All of the information shown was produced automatically: the grid numbers, the grid itself, and the contours. The mathematical generators are the Control Graticule and Grid System and the Automatic Grid and Projections System; the latter was used to generate the grid. The system used for the open windows (area fills) is semiautomatic: the area is outlined, then the precision plotters are used to plot the boundary of that area on Peelcoat, and finally a photographic screen is used for the area fill.

Sharp: With this conference the professions are beginning to communicate. Not only are the surveyors talking to the cartographers, but three automated processing professions are also participating. Two of these professions are well-developed--automated photographic processing and automated lithographic processing. The third, automated data processing, is new. We used to send our work to the photolab or the lithographic department and complain that it didn't get out for weeks. Now we send it to the data processing department and complain when we don't get it the next day.

Conflicts within and among the professions can only retard our progress. The system presented by Cook, for example, was produced with the cooperation of people of varied capabilities. Communication helps economics as well as technology. We aren't really professionals unless we're concerned with economics. This concern involves defining the type of points, lines, areas, names, and symbols for our product; collectively treating point data bases, line data bases, and area, names, and symbol data bases and examining products for content, addressable points, reproducibility, accuracy, readability, and credibility--we've been calling it topo license.

We use equipment costing from $3 to $300/hr, materials costing up to $25/item, and people costing from $5 to $15/hr. Quantity also affects cost. National Geographic may make about 6 maps/yr, but they deliver them to 6 million people, whereas USGS makes about 2,000 maps and 5,000 copies/map. Both quantities are large, but they involve different problems and different economics. Both high- and low-cost equipment is used. The small user can buy low-cost equipment, but he must share high-cost equipment to be economical.

Don't get caught in one school of thought. You an produce interactive or off-line graphics, you can perform forward or on-line editing, and you can put 1 to 4 tables on-line with one computer. Give the production people the tools, and let them decide what is more economical. I think that we are becoming economically and professionally responsible.

Thorpe (Natural Environmental Research Council, U.K.): Could members of the panel comment on their efforts and achievements in automatic name placement? Also, have you used or investigated any of the CODASYL data management languages for cartographic data handling?

Porter: We have done neither. Names are still placed manually because it is more cost-effective. We are now building a file management system which we hope is more suitable to cartographic data than the one proposed by the CODASYL committee.

Stine (Chairman, ICA Commission III): Throughout the week I have heard the hue and cry that no one is taking care of systems for the small man. Then Wickham said that private industry and local governments are working with systems. If they are, and I know that they are, it is one of the best kept secrets in automated cartography. Commission III of ICA has repeatedly asked for papers about the small systems, but I cannot find anything in writing about them. I gave the chairman of this conference the name of someone who is operating a very elaborate system, and he wrote to this man, but he was too busy to come to the conference. Commission III, which is supposed to report developments in automation, really needs to communicate with these people.

Sharp: Private industries and local governments have been busy staying solvent and really working, while most of us have been involved in devellopment. I want to show a picture of a system that scanned and digitized about 15,000 sheets. This system hasn't had much publicity recently. Tomlinson, would you comment on this system?

Tomlinson (Chairman, IGU Commission on Geographical Data Sensing and Processing): I must speak unofficially about this system which is in the Department of the Environment in Canada. I helped develop this drum scanner in 1962, but I have not had anything to do with it in 4 yr. Soil maps, agricultural land charts, or any type of polygon data are put on the drum. The drum revolves and the data are scanned in 2 to 15 min. The tapes are processed separately and go into a storage bank of maps. The file structure covers all of the populated area of Canada, about 1 million $mi^2$. There are 11 different types of data in the system now, and it has been fully operational for about 3 yr.

There is a great tragedy here. The Department of Energy, Mines, and Resources has an excellent system that digitizes maps and puts all the data in one file format. Another government department has another system that digitizes maps in an entirely different file structure. At some point the systems will have to be compared, and somone will have to change. All the maps in one file format will have to be converted into another format, a process that may be impossible without redigitizing the maps. I suspect that this situation is happening in the U.S. and elsewhere. Conferences such as this one should more thoroughly consider the question of compatible file structures.

Ward (Central Intelligence Agency): Cook or Sharp, are you finding it cost-effective to use your system for automatic name placement?

Cook: Yes, we are, mainly because of the speed with which we can lay the name down.

Ward: What is the factor of improvement over the manual system?

Sharp: At least 5-percent improvement.

(Unidentified speaker): It takes half a minute with vector technology and vector digitizers. With the development of raster digitizers automatic placement of names should be more rapid and more economical.

# Closing Session

## Open Discussion--Whither by 1984?

Morris M. Thompson, Presiding
U.S. Geological Survey

Thompson: The title of this open discussion, "Whither by 1984?," was selected by the conference planners. When I saw the title I wasn't quite sure whether they meant what will happen 10 yr from 1974, or whether they specifically had in mind the magic year 1984 as presented in George Orwell's book 1984. I read the book in 1949 when it was first published, and it made quite an impression on me--I still remember it. However, I did get a paperback edition (I think the 27th) to refresh my memory. You may remember that Orwell was predicting a social system 35 yr in the future. In 1949, 1984 seemed very far in the future, but it is not such a long time now. I thought that it would be interesting to relate Orwell's predictions to cartography in 1984.

I have composed a credo for cartography in 1984 (fig. 1) based on Orwell's credo for ENGSOC (English socialism in 1984)--"Freedom is slavery, Ignorance is strength, War is peace." After listening to the proceedings of the first 2 days, I think that the cartographer's slogans for 1984 will be: Manual is slavery, Digital is strength, Automation is peace. The overriding slogan of 1984, "Big Brother is watching you," can apply equally well to Orwell's society and cartography. Although it is not yet 1984, you can go into any department store in this area during the Christmas season and Big Brother will be watching you through television. Before very long we will have the two-way television screen in our homes with Big Brother watching us. We are approaching this stage in cartography with interactive systems that can operate in both directions.

In 1984 will I have one of Boyle's floppy cartographic disks to carry with me on trips instead of a road map? What will happen in 1984?

Boyle (Univ. of Saskatchewan): I have been thinking about 1984 because if you want to design something for next year, you design it for 10 yr in advance; it takes that long to develop it. We do a lot of bibliography searches. Extracts from different reporting systems come to us every month. Since I never have time to look at them, they gradually pile up and are thrown in the waste-paper basket. I keep asking for magnetic tape. We could put the tape on our system, find out what we want, and then ask for it. But they don't know how they would be paid for it, and they think we might copy the tapes--a nonsense situation. In 10 yr many people will use geographic information systems, and they will expect to get cartographic data on magnetic tape. Supplying tapes will be routine then, whereas now it is exceptional. Whether we will still have the drawn map in 1984 is debatable.

| 1984 ORWELL | 1984 CARTOGRAPHY |
| --- | --- |
| • Freedom is slavery | • Manual is slavery |
| • Ignorance is strength | • Digital is strength |
| • War is peace | • Automation is peace |

BIG BROTHER IS WATCHING YOU

Figure 1

Fetter (Southern Illinois Univ.): A few years ago Dr. Gil Hollingsworth, then head of the Boeing Scientific Research Laboratories, described in a paper the length of time between proving a product in the laboratory and implementing it. He decided that photography would take 100 yr, solid state 5 yr, and so on, with everything converging about 1984.

Yesterday somebody said that information must be in a form that local people can understand, and today somebody said that we must reach the sublocal people. Perhaps we have all the systems necessary to bring this information to the individual in a form that he can use. The best example right now is satellite weather maps on television. While television is not an appropriate medium for cartographic precison, it should not be discounted as a means for conveying information. With increased awareness of natural resources individual decisions have big impacts. Perhaps now it would be helpful to have a map on television that showed contours indicating areas of equal prices for sugar.

The wide-angle projection system at Boeing began as an idea for displaying global data without distortion in a compact airborne space. The idea was very much like a planetarium, with a display on the inside surface of a sphere. We built a program that acted like a fish-eye lens. At Southern Illinois University, I am studying this system again because I am beginning to see applications far beyond global display. We have made a 70-mm test slide, which earlier this year I placed in the Boeing Spacearium setup. It worked beautifully. Our next step is to write a proposal for 70-mm film so that we can display not only a hemisphere of the Earth, but also motion in order to see changes in Earth resources or other themes.

Being immersed in an environment, rather than just seeing a small section of it, has several advantages: your whole body--kinematics--helps you to interpret distances and spaces, and the focal distances are identical to each point on the surface. This type of display will be useful for air-traffic display and three-dimensional displays such as the geographic horizons of interest to oil companies.

We are also studying virtual image use of digitized matter. We have a prototype syntholizer designed by Roger De Montabello. We hope to demonstrate how geographic data can be placed in this three-dimensional region so that you can walk around and see it; even though it doesn't exist in three-dimension, it appears to. It is technologically at a lower level than holography. We think that both of these developments, particularly when combined, will offer some interesting opportunities.

Aangeenbrug (U.S. Bureau of Census): Some years ago several Federal agencies working together completely automated the activities of several U.S. cities. This work is a well-documented failure so far, but it is also a small success. Wichita Falls, which had a reasonably good data base for some of its operations, discovered that the contract for cable TV would allow two-way communication. At an informal session the council discussed the possibility of controlling the TV and of reminding people on the TV of overdue water bills. One councilman even suggested that this might lead to manipulating the TV environment of that individual.

Also in Wichita Falls the local decisionmakers were unaware or impatient with the "right" map. To them the only right map was one that was readily available and that they could understand, regardless of the cartographic skills or the money required to produce them. One of the biggest threats or opportunities to traditional cartographers is that they must produce a map that people will understand even though they don't quite agree with it. Cartographers shouldn't eliminate basic and serious research and development, but unless they produce these maps, someone else will. Once I showed a three-dimensional model of housing values to a Secretary, and he understood it. Jenks said that the class intervals were wrong, and Corbett and other technicians said that the colors were wrong too, but the Secretary liked it.

Ward (Central Intelligence Agency): A safe prediction for 1984 is that Murphy's Laws will continue to operate. Some of you are familiar with Murphy's Third Law--if anything can go wrong, it will--but I would like to remind you of the first two. Murphy's First Law is that nothing is as easy as it looks. His Second Law is that it always takes longer than you think.

Finnie (Private consultant): Using Murphy's first two laws, I would like to project changes for 1984 based on the changes that were supposed to take place in automated cartography from 1965 to 1974. In 1965 Radlinski and I served in the same kind of working group for the Bureau of the Budget that Southard talked about. After studying six major areas, one of which was automated cartography, our panel investigated the status of research and development for automated color separation. The equipment displayed this afternoon existed in 1962. Prototype raster scanners were to be operational in 1969. Before 1969 we were to be able to color separate maps and charts at one-tenth the 1965 cost.

After 5 mo in the working group, I returned to production and made one big mistake. Thinking that we would have to change to automated cartography in 4 or 5 yr, we contracted more work and did not recruit replacements for people who retired or changed jobs. In 2 yr I checked on the progress of the raster scanners; and the drawings and concepts were the same ones that had been explained to me in 1965. These same scanners are still in the labs. That they aren't replacing people doesn't mean that they won't, but development moves slowly. Military cartography is making progress in automation because the user needs digital data rather than analog data for maps and charts. We have plenty of examples and an enormous amount of capability to produce digital data. Anytime that you can produce digital data as an output, you can take advantage of that cost of production to automate your mapping processes. By 1984 military cartography will be more automated than civilian cartography because military requirements for digital data are increasing rapidly.

Doyle (U.S. Geological Survey): How many slaves will we have in the Geological Survey in 1984 if "manual is slavery"?

Thompson: 1742, I think.

Doyle: Digitization and automation can take place at various levels, but sooner or later in the cartographic process someone has to make decisions. The automation of those decision points is beyond our scope at this time. We may be able to replace the lower level scribers, but a top level of people will have to remain as the decisionmakers and continue to be slaves.

Colvocoresses (U.S. Geological Survey): Automation is not necessarily synonymous with digitization. The National Oceanic and Atmospheric Administration is enhancing band 7 of ERTS imagery (which was digital to start with) and making their water plate thematically--a step in the right direction cost-wise and it did not involve the digital process.

At the first meeting Radlinski presented an equation which states that map value is a function of content, completeness, clarity, and preparation time. I think that Rad has omitted a critical factor--spatial accuracy. I also think that time should be taken out of the denominator and put in the numerator. If we can agree on criteria, I am most anxious for some of our maps to be evaluated with this equation so that we can find out what we are getting for our money. The time has come to put a quantitative value on our maps to monitor our progress in this field.

Boyle: I've heard no mention of metrication. Is the U.S. converting to the metric system? If so, perhaps 1984 is a good target date.

Edson (U.S. Geological Survey): In 1984 one of the ingredients in cartography will be man's increased intellect. Man's interest in maps coupled with this heightened intellect will increase his desire for knowledge about his environment. I foresee a continuing and expanding need for the graphic as well as the digital product.

Brassel (State Univ. of N.Y.): The alternative to slavery and ignorance is education. For the next 10 yr education and training in map reading will be very important. We are able to represent facts or concepts that are very difficult to read. Most of you say that we must simplify our maps, but also we must educate people so that they can read the concepts represented.

Aangeenbrug: One of our big problems is that we are professionals worshiping at the shrine of automation. Quite often, we are perceived as casting pearls at the citizen swine. However, many decisionmakers are quite smart. We must assume that people can learn and then provide the tools and training to see that they do. We should ask rather than assume that people can read our maps.

Moritz (PRC Information Sciences Co.): I expect that the cost of digital processing will come down significantly. Nowadays a 50-cent piece of film is replacing digitizing equipment costing over $100,000. Our biggest problem will be deciding how much data to keep and in what form. Telecommunications is going to have a great impact on the transfer and standardization of data. Information from national data banks will be made available by sending film through the mail or by using inexpensive telecommunications equipment, such as teletypewriters or small cathode-ray-tube consoles which are well within the budget of most State and local users.

Thompson: This message comes from one of our recording monitors, Madonna Elliott, who is a civil engineer in the Topographic Division of USGS. Madonna says, and I think it is appropriate, "I would like to see more women in cartography by 1984 than I have seen here this week."

Bockes (U.S. Dept. of Agriculture): In 1984 will we be able to come to USGS and get digital data just as we now get maps?

Thompson: Tomorrow morning we will give you some, if you ask for the right data.

# Summation

Dean T. Edson
Conference Chairman

Warren E. Schmidt
Program Chairman

A. Raymond Boyle
University of Saskatchewan

Michael McCullagh
University of Nottingham, U.K.

Edson: I would like to conclude this meeting with brief observations from three participants.

Schmidt: First, I want to thank the many people behind the scenes who put weeks of effort into this conference and the U.S. Geological Survey for providing this beautiful facility--actually this conference is the first large meeting to take place here. Credit also goes to some other agencies that supported the conference--the Bureau of Census, the Central Intelligence Agency, the National Ocean Survey, and Harvard University. Last but not least I thank the chairmen, panelists, and all committee workers.

Two goals of this conference were to be comprehensive and to get people of similar interests together. I think everyone will agree that the second objective was accomplished. As for the first objective, we were comprehensive in scope but not in depth. Because of time limitations each topic could not be covered completely. Many fine programs and efforts were not even mentioned: the surface representations of Bob Samson at Kansas University, the direct digital inputs from photogrammetry and scanned satellite photographs, the important works of Junkins and Junkietis at the University of Virginia, the ASIPS plotting programs done by FORSIC at Ft. Bragg, N.C., and the program libraries of National Technical Information Service and Professor Wittick at Michigan State University. What is the solution? Moritz suggested that future conferences treat either hardware or software alone.

Again, thank you for your participation and patience.

Boyle: One concern of this conference has been the little guy. He needs the facilities for professional digitizing and drafting, but they aren't available to him. One reason is the lack of support from Federal organizations. The Government departments are very busy and consequently not really responsive to the small user's need.

The conference discussion also showed concern for what I would like to call "dogmatic all," a term borrowed from logic design. I refer to having to choose between incremental or absolute coordinates, or to choose between lines, polygons, or grid cells. I don't believe in this, but rather that a mixture of spaghetti and ice cubes can work and be optimized for special jobs. Several times I felt that the audience inferred a definiteness from the panelists which I think was not intended or needed.

McCullagh: In the software sessions the emphasis of the panelists was on data input, editing, and storage. Little concern was shown with analyzing the input data. A big advantage of digital input is that you can analyze the data and display it in modified form. We should produce maps that are analytical products. Maybe the argument against analytical maps is that if you are producing topographic maps or specialized maps in large quantities, it may be difficult to also produce analytical maps. Maybe such analysis is more of a research necessity. Perhaps when we begin producing vast numbers of topographic maps for the smaller users, we should also produce analytical maps for the local levels. Maybe we could produce a series of analytical maps for every topographic map. Since the information is available, a relatively small amount of digital processing would produce the map very quickly.

In software development, pseudo-interactive systems will become important for the smaller user. Systems like INPOM and ASPECTS, which give a small and nasty result but nevertheless a view of the data, will also become more important. These systems are not only quick, but small enough to fit on the small user's computers.

We should be making computer software systems usable. At present they are not usable by noncomputer-trained cartographers. The producers of new digitizing systems are trying to avoid this problem. For instance, at Kansas University Professor Nunley has a project that has little to do with cartography except that it produces maps. Instead, the project is concerned with making the user comfortable--when he is sitting in front of the computer, he has a nice chair, shag carpet, and so on.

In the future we must be concerned with the needs of industry and research. We have heard a great deal about the necessity for education outside industry, for the users of these maps, but maybe we need more education inside industry. In-house cartographers and draftsmen could be taught the necessary skills in their own organizations. Education is usually the only way to get people in other fields to become useful and accept new principles.

Considering accuracy versus time and cost--maybe we don't need accurate topographic maps, but generalizations with reasonable accuracy. Perhaps industrial organizations are going overboard on the accuracy criterion for much of their mapping. It must be cheaper and quicker to be less accurate.

We also have various research needs. Harvard is working on color implementation, and the Computer-Aided Design Department at Cambridge, England, is using color to display three-dimensional images (Scientific American, May 1974). Perception cartographers and software cartographers need to communicate--on the whole they don't understand each other. We also need to produce plastic bottles more cheaply. We must investigate new pastures.

Edson: In concluding this meeting, I will tell you a few facts about this conference. Over 360 people representing 200 institutions, 50 professions, and 11 countries, including the U.S. and Texas, have attended the sessions. And the proceedings have been carefully recorded on about 5 miles of magnetic tape.

In his keynote address Radlinski challenged us to talk to one another, and I believe we did. But the communication must continue. If you have found fault with this meeting in some way, I reluctantly ask you to tell me. I am not offering to conduct another meeting, but I assure you that constructive remarks will be passed on to anyone who has the courage to plan the next conference. If you think the conference has been worthwhile, tell your friends. And by all means, keep talking to one another. This meeting and the 1969 parent meeting are two points on an exponential curve of learning. Let's keep it on the rise.

Aangeenbrug: The Director of the Bureau of the Census is particularly concerned about the growing technological problems in map perception arising from the use of computer microfilms. We have interested several other agencies and the National Science Foundation in a conference for spring 1975, which will probably include discussions of perception, data bases, and networks. The 1975 conference will be followed by two conferences in 1976 and 1977. Attendance at the 1975 conference may be by invitation only because we want to have more working sessions. If you are interested, write me and I will keep you informed. I think the next conference will also be godfathered by the skilled chairmen of this conference.

Edson: My final remark is in tribute to my coworker, Warren Schmidt, who has spent so much of his time on this conference. I declare the meeting adjourned and thanks for coming.

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