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The Changing Scene in Surveying and Mapping*

The National Mapping Program will move from the task of preparing maps to creating and maintaining a national digital cartographic data base from which many products, analyses, and services will flow.

As I look around the room, I see many friends that I have known a long time. Some of us served during World War II when we were young. We came home to pursue educations in land surveying, or civil engineering, or cartography, or geography, or Earth science, and we entered the profession of surveying and mapping at a time of great change. It was for me, and I trust for some of you, the opportunity of a lifetime. We and our leaders helped spearhead the development of photogrammetry as a universal technology for surveying and mapping. It was one of the most significant changes in mapping's history.

The late 1960's and 1970's saw the development of still more sophisticated techniques for our professions. Applications of photointerpretation proved extremely valuable, and through those early days remote sensing became a science. The use of satellites for geodetic positioning and mapping is growing, and several countries are now planning additional satellite systems for even further applications in those fields. Most rewarding of all is that our work is growing in recognition, in importance, and in usefulness. The Nation deeply and increasingly needs the special talents of our professions. There is hardly a question about the lands, the ecology, or the environment that does not require that someone somewhere turn to a survey or a map for information. I believe that this recognition stems from two important characteristics of our generation of surveyors and mappers. One is a shared vision; the other is a willingness to change. We shared a long-cherished vision "to map this nation," which was first put into words by John Wesley Powell, the Geological Survey's second Director, almost a hundred years ago. Today, at long last, it appears that we will see that vision fulfilled in our lifetime. Secondly, we have not and must not hesitate to change, to innovate, to apply advanced technology to a highly traditional profession.

We remember, for instance, in the 1940's that aerial photography was still highly suspect as a tool for surveying and mapping by many in our profession. Ours was the generation that took this powerful technology and applied it to cartography with great success. This was indeed a revolution. Unlike so many other revolutions, however, ours remained true to the order and integrity of the heritage of our profession. It was a revolution without revolt. These two characteristics, the shared goals and a willingness to change to meet exploding requirements, will be indispensable factors in the way we address the future. The future will challenge us greatly and ever increasingly. It will demand new goals and a willingness to innovate as never before. Scientific advances have come to surveying and mapping and continue to come—almost in an overwhelming way. We must respond positively or else these scientific advances will roll over us, leaving us behind as the buggywhipmakers of surveying and mapping.

Let us talk about the shared goals. Since stated a century ago by Major Powell, surveyors and mappers have sought to map this Nation in standard series with fidelity and high scientific accuracy. The recent superb volume, *Maps for America*, written by our friend Morris Thompson to celebrate the Survey's Centennial, chronicles this story very well. Nevertheless, for 60 years in that 100-year period, the project to cover the country with useful maps moved ahead very slowly, too slowly. Today, however, we are nearly four-fifths finished with the coverage of the country with maps at 1:24,000 scale, with most of the maps up-to-date. Very soon we will have complete orthophoto coverage of all of the remaining

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unmapped areas, while we continue pressing toward the coverage of the country by conventional line maps. Well within a decade we will be finished with the coverage of the line-map series, with the exception of Alaska, which will be covered by mile-to-the-inch mapping or larger as required. Another important aspect of our completion of this task is that national mapping will be accomplished now with substantial assistance from contract mapping firms—a new thought for the Geological Survey and one that is working very well. The near completion of this task means, as we knew it would, that we have to establish new goals for our profession and, at the Geological Survey, we have to establish new goals for the National Mapping Program. As we did in the past, we need to find new and better ways to serve the cartographic needs of the Nation.

The Federal Mapping Task Force in 1972-73 very clearly pointed to the need for re-evaluation, resetting of goals, and for reorganization to meet those goals. I believe the Nation's need for data about the land puts us at a very critical point between the scientists who collect and analyze those data and the people who need that data and information in order to act. As surveyors and mappers, we probably recognize better than most the value of information with a ready means of portrayal and how the lack of it can handicap communication. It has been our role over time, and it will continue to be our role, to present Earth-science information in ways that allow people to understand it and, therefore, to act and make decisions about it. That role is changing, but not in importance. It is a role that must deal with new sciences and the technology of data processing and electronics.

These new forces change completely the nature of the Nation's need for cartographic services and, more importantly, the way users perceive their need for it. Maps, it seems, are no longer enough. For some, maps may not be necessary at all, but needs may be satisfied by just the data in some form. For those of us in surveying and mapping, we must face the implications of computer technology, and much more than technique is at issue. I am not talking about a better way to scribe roads on mylar sheets. I am talking about nothing less than our ability to serve the cartographic needs of the country. Also, more than science is at issue. It is the extent and shape of the very essential Government functions of surveying and mapping and how they must be changed and keep changing to meet the needs of society. From the beginning, we are the ones, we the mappers, we the surveyors, who have brought together many different kinds of data and information from many different sources—from surveys, from imagery, from photogrammetric compilations, from other maps. We have analyzed it, we have organized it, we have portrayed it as a series of maps. This process, of course, has continued to smooth out and improve over time, but it has been relatively slow and insufficiently responsive. Now, however, the process has been caught up by the computer revolution. Computers give us extraordinary powers to collect, analyze, organize, and portray information. Applied to cartography, computer technology enables us to collect and portray large amounts of data, once the data have been correctly accessed and organized. The promise of computer technology for the field of cartography really comes down to this: it will allow us to do what we have done before, except do it better, do it a lot faster, and do more of it.

I would like to tell you how computer technology and its applications will affect the National Mapping Program. This is a discussion based on what we believe to be feasible, right now, with state-of-the-art computer technology. As the Nation's cartographers, we sought coverage of the Nation in standard series of maps. In addition to the nearly four-fifths of the Nation covered by the 7.5-minute quadrangles, there is considerable coverage at other scales and formats. Integration of computer technology into the National Mapping Program does not mean that we will cease making maps or that we will neglect completing the coverage at the basic scales, either the 1:24,000 scale or the new 1:100,000 series, the first full metric series in our bag of tricks. We will continue updating the 1:250,000 series, which is the largest scale series currently covering the entire United States.

Therefore, maps and mapmaking will continue to be a central part in the National Mapping Program. What will change is that each of the traditional steps in the process—collection, analysis, organization, and portrayal—will become important and distinctive parts of the program, no longer just a means to the production of a paper map. For some users the maps will always be the answer to their needs. For others, just parts or components of the cartographic process will be their answer. For still others, the entire process will be required to meet their needs. Some products will be in the form of pure digital data; other products will be analyses from those data; and still others will be graphic formats or maps that can be manipulated and made responsive to users' abstract reasoning and the computer.

This emphasis on the entire process means a major transition for us over the next decade. We will move from the task of preparing maps, or our one-product family, to creating and maintaining a national digital cartographic data base from which many products, analyses, and services will flow to our customers. The categories of information in the data base will be those represented on topographic maps: terrain, boundaries, hydrographic features, transportation, land nets, surface cover, survey control, reference systems, and so on. This data base and components will allow customers to design their own products by taking information from the data base, combining it with information of their own, and portraying it their way. The national data base will allow us to automate production of maps as well as to introduce new graphic products. We will be able to offer people their own tailormade maps as products—tailormade products at scales and with features specifically suited to their own needs. Significant amounts and classes of data will be distributed directly to customers in digital form without graphic portrayal. Establishing this digital cartographic data base and network will encompass five important functions: data acquisition, digitizing, data base management, output products, and customer services.

Data acquisition, the first of these functions, will emphasize collecting and updating the various categories of information needed in the data base. It will have a very interesting effect, we think, on the way we revise maps. As we move into digital cartography, the focus of revision will change from doing specific geographic areas exclusively, such as a quadrangle, to collecting data on classes of information. It will be revision of a data category rather than revision of a specific map. This also means that we will begin accepting and searching for data from other sources beyond our own field and aerial surveys. Other Federal agencies and State agencies will become primary contributors of important classes of information, such as transportation and boundaries. We will establish agreements with these organizations so that data can be provided regularly and in correct format. The basic change in the way we collect information, of course, will affect our traditional production. It will shift from compilation, per se, and publishing, to collecting data that are not available from outside sources. Given the role we have played in the past, we can assume that we will continue to be responsible for lifting themes and data that can be extracted from imagery. Also our heritage in topographic mapping helps us to deal with elevation data or terrain data.

The second function is digitizing. At one time, the major components were a surveyor and his instruments in the field and an airplane with cameras in the sky. Today there are many other components—a variety of spaceborne instruments, state and county road departments, water resources agencies, natural resources departments, and environmental quality organizations to list just a few. One of our primary services, therefore, will involve the translation of visual or graphic information into digital data. We have nearly 39,000 published maps in our inventory, which will translate into an immense amount of digital data. Other data will be digitized from new mapping projects and from stereoscopic compilations. When all these data have been entered into the data base, the work will have been reduced, but not the significance of the capability to do it. Consider, for example, the capability to combine temporal graphic information, such as space imagery, with existing cartographic data. This is simple expression but it describes a very difficult task, especially if done in the traditional way we have previously approached the combination of data sets. Using a mapping satellite, and combining its imagery with other data, such as rainfall measurements, we would be able to plot near real-time effects of a major storm. The likely paths and volumes of rising water could be predicted with reasonable accuracy, and graphics could be displayed that combine and correlate these data so that people could take action quickly and intelligently to save lives and property. The opportunity is, therefore, for the production of maps that move. These will be dynamic maps, maps that reflect temporal phenomena and allow us to predict future phenomena. Such a case, of course, is the excellent Forest Service concept of Firescope, which would combine accurate topographic data with meteorologic data to help control fires and other hazards. This dynamic cartography, and our way of dealing with it, is going to be essential to people who can apply it.

The third function is establishment and management of a massive digital cartographic data base, and massive surely is the working word. Estimates range widely on the eventual size of the data base, and, of course, we can and must execute some control over that. Some believe that it will be as much as several billion bytes of data, either on magnetic tape or in laser-optic storage systems. Which estimate one accepts depends on the assumption one wants to make about the resolution or level of detail that will be needed by the users and the part that the Government should be furnishing.

In the National Mapping Program we are beginning to build digital data bases. At the moment we are digitizing the two-million-scale sectional U.S. maps from the National Atlas; they will be in digital form by next spring. For the main data base, however, we plan to digitize the 1:24,000-scale topographic quadrangles, a task we believe must be finished by the early 1990's. This data base and its supporting systems will be the heart of the National Mapping Program within the near future. Large budget outlays will be required for storage and processing facilities, as well as for the data entry or data production activity. The data base, which will be a national resource of potentially enormous benefit, will require national standards for data formats, codes, and accuracies so that as many agencies as possible may benefit as well as contribute to it. A major responsibility faced by the Geological Survey is to lead this effort of establishing standards. This very ambitious data base must be so designed and constructed that other data bases can be combined or reconciled to it. Data bases such as geology, soils, and land use, for example, should be able to combine with the cartographic data base in much the same way these disciplines now use topographic maps as a base and framework for the clear portrayal of scientific studies. The question of Governmentwide standards for data formats, codes, and accuracies is a difficult one, but it is being addressed. An agreement has recently been signed among the Defense Mapping Agency, the National Ocean Survey, and the Geological Survey to pursue actively this question in a pragmatic, implementive way. This agreement is an important step because all these agencies are currently involved in data base development on a national scale.

A fourth major function is the preparation of graphic products as an output of this "all-singing, all-dancing" data base. This will be an exciting field for valuable applications of digital cartographic data. One of the graphic opportunities will be the automatic production of pressplates. Technology is near at hand for automating, almost entirely, the steps involved in making pressplates. This and other efficiencies will mean that we can shorten considerably the several years it now takes from aerial photography to printed product to make a map of a previously unmapped area. The cycle has been as long as four or five years, and it must be shortened. The Federal Mapping Task Force reminded us in 1972-73 that "those are great maps but who can wait five years for them?" Another graphic output, using computer techniques developed by the USGS Branch of Astrogeology in Flagstaff, is a shaded relief product produced from computer tapes. This shaded relief presentation is needed because of the special expression it adds to the conventional map linework. I believe that by the 1990's we will be close to a capability of producing instant maps. Existence of the cartographic data base will bring about the day when communications technology will allow a citizen to order the map he wants at the local retailer or even in his own home. He will be able to specify the scale and features he wants. He will know at once whether the map is up to date or not and be able to tell us immediately. The map will be printed for him over a home copier or even at his local retailer. Through the use of interactive software, he may be able to do route planning faster and more conveniently, for example, and in the privacy of his own office rather than at a local automobile club. The opportunities are staggering for putting cartographic information to work for us in our everyday lives.

The fifth important function, and definitely not last in importance, is customer service. In the old days, the extent of customer service was helping someone find a map he wanted. By the 1970's, though, we recognized that this service, important though it was, was simply inadequate for the mapping needs of the Nation. The great wealth of cartographic data that was available, done by Federal, State, and local agencies all across the country, had been paid for with taxpayers funds, and we were shorting the taxpayer by not helping him find the data more readily. In response to this perception, the Geological Survey formed the National Cartographic Information Center, which was an attempt to solve the problem. Of course, the problem is not entirely solved at this time, but it is much, much improved. The initial purpose of NCIC was to be responsive to users, to find information for them if it existed, and to furnish a set of products that would help them find it themselves. We now service thousands of customers through NCIC offices and affiliates. They purchase space and aerial photographs, map feature separates, digital terrain tapes, geodetic information, microfiche indexes, microfilm and microfilm copies, and even diapositives from which they can make their own maps.

Digital cartography, however, is going to require a quantum jump in our ability to be responsive to customers. We intend to provide technical assistance in digital cartography which will develop the expertise needed by customers in order to work with digital cartographic data. Providing technical assistance will be particularly important because the sophistication of users in digital cartography varies widely. We intend to develop multipurpose software systems, such as overlaying techniques, and to construct geographic information systems to help meet customer needs.

All of these five functions—data acquisition, digitizing, data base management, graphic product output, and customer services—will become major elements of the National Mapping Program during the 1980's. In concept, they continue to embody the historic role of cartographers. The same role of collecting, analyzing, and organizing data, and portraying the features of the Earth accurately and clearly will continue. But the changes necessary to accomplish a transition—to do the same things differently yet responsively—will be enormous.

The Geological Survey is planning to meet this challenge. The Secretary of the Interior and the Director of the Geological Survey have taken an interest in the advancement of digital mapping and are giving us their strong support. We believe that we can also expect good support from the budget process. Another way the USGS is preparing to meet the challenge is by reorganization. The Director has sent to the Department of the Interior for approval a merger plan for the Topographic Division, Publications Division, and Geography Program. The proposed merger will combine the National Mapping Program, the excellent land-use/land-cover program of the Geography Program and the related research and analysis, the cartographic support for other USGS programs such as geology and hydrology, and printing and distribution of cartographic products. This is a very strong move by the Geological Survey to do what the Federal Mapping Task Force suggested in order to make the mapping effort even more meaningful and more responsive. The combined strength of the Topographic Division, the Publications Division, and the Geography Program will provide a means of expanding and enlarging our response to national requirements.

Another way the USGS is preparing to meet the challenge is by improved coordination within its own agency, with the Geologic Division, the Water Resources Division, the EROS Program, and so on. In the past, there was insufficient coordination of matters related to mapping. We think that improved coordination is very important because of the national priorities that we have, so we are trying to make our program more responsive to the other parts within the Geological Survey and to other bureaus of the Department of the Interior. We are actively coordinating with other Federal agencies. We have continuous coordination with the Defense Mapping Agency. We also have very active coordination with the National Ocean Survey, Bureau of Land Management, Soil Conservation Service, Forest Service, and many others. We are getting both advice and assistance from all of them, and the whole activity is a great deal stronger for it. We are conducting a great deal more active coordination with State agencies through NCIC and their affiliates, and with State mapping advisory committees, and through sponsorship of regional conferences.

The Geological Survey is making a considerable case of the need for more and better cartographer education. Courses need to be modified, strengthened, and updated in many schools and universities. Some of you are aware of the study that is being done by Dr. Richard Dahlberg of Northern Illinois University, in which he is conducting an inventory of education in the mapping sciences. The result will be a useful product and a useful data base for all of us.

The story that I have just told about the changing and maturing of the National Mapping Program is similar to what is occurring in many other programs and agencies. A local example of that, for instance, is right here at Sioux Falls at the EROS Data Center. The EROS Data Center (EDC) is a very strong partner in the National Cartographic Information Center complex. The imagery data base is here, not only for Landsat data, but also for a great deal of aircraft data. Being able to keep track of over 6 million frames of data and all the orders and accounts that flow in allows NCIC, with help from EDC, to offer prompt, efficient service on all USGS- and Interior-held products. The system will continue to be improved to handle even more customer orders and advanced products, such as the satellite images processed through the new EROS Digital Image Processing System called EDIPS. EDIPS and the NASA facility known as IPF (Image Processing Facility) promise to provide improved service to users of Landsat data across the spectrum. With use of the satellite data relay, DOMSAT, the time between data acquisition and its availability at EDC can be reduced to a few days. Also, Landsat is now being fitted to ground control in many areas, which can improve its geometric accuracy. Finally, new methods in image processing indicate that image quality will be far superior to that now processed prior to the IPF/EDIPS effort. We look forward to continued development by EDC in the areas of product and services development. In the Defense Mapping Agency, both at their Hydrographic/Topographic Center and at the Aerospace Center, enormous strides are being made in the application of advanced technology in geodesy, photogrammetry, automated cartography, and new products and services for military users. Also, as mentioned, a great deal of close and helpful cooperation is being extended to civilian mapping and charting agencies on a continual basis. At the National Ocean Survey, automation in nautical charting is operational, and the automation of aeronautical charts is an active development. The National Geodetic Survey is actively pursuing the North American Datum Adjustment, hopefully to be completed in 1983. Also, at NOS, in the aeronautical charting areas, Minimum Safe Altitude Warning data are being furnished in response to FAA's requirements at major airports all across the country. NOS is the major producer of those data with a little help from USGS. It is an excellent system that works well.

Everywhere the story is similar. More and more uses are being found for the products and skills of surveying and mapping. Users are hungry for the data and they want more, and faster, and better, and most of them need some help in finding it and using it when they get it. More and more of the data are wanted in combinations: survey location, ownership, terrain data, hydrography, transportation, soil, surface cover, on and on. Can we escape concluding that among us, in surveying and mapping, there is a partnership, even if at times a fretful one. The land surveyor, the photogrammetrist, the cartographer, the geographer, the geologist, the soil scientist, and others—before long, we are all going to be held accountable for getting our act together. The users out there do not care where those data come from, they do not care whether it was a land surveyor that turned it up or a cartographer, photogrammetrist, geographer, university professor, or what; they just want it and they want it to work when they get it. That is the charge we need to place on ourselves. It is a tall order, but for surveying and mapping at least it begins right here. What I do and what you do will definitely have a bearing on our joint success. It is the opportunity of our lifetimes.