marking the locations of underground facilities because this would simplify their administrative and logistic problems. From the point of view of highway departments, a color code would make the underground plant within the confines of the highway right-of-way easily identifiable by maintenance crews.

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Computerized Mapping and Record Systems for Utilities

E. C. Jenik, American Telephone and Telegraph Company, Basking Ridge, New Jersey

In the telephone company, the outside-plant-location record is the permanent inventory of all outside plant in service. It serves as a primary document and tool for engineers designing additions, deletions, and changes in the plant. The use of this record is described briefly. The drafting effort required to maintain this large data base is discussed, and the difficulties in maintaining it by manual methods are emphasized. Explorations into applications of computer-graphics technology are reviewed. The implementation of a pilot, interactive-graphics minicomputer system that completely automates all drafting of outside-plant-location records and engineering work orders is described. This system is an on-line system that replaces paper records by electronically stored records that can be accessed and retrieved by a computer in real time at interactive-graphics terminals. It is used to demonstrate how future drafting and record drawing can be performed on displays at cathode-ray-tube terminals. It is cited as an example of a specialized computer-assisted, map-based record system. The advent of this new technology is a result of recent developments in computer hardware, computer systems, and digital graphic systems and has led to many new proposals for joint-use systems that have a common, fundamental map base. These are described in terms of their impact on land-ownership records. The efforts of the American Public Works Association to develop standards for this field are reviewed and the aims and purposes are described.

In the telephone company, the outside-plant-location record is the permanent inventory of all outside plant in service. It serves as the primary document and tool for engineers making additions, deletions, and changes in the plant.

Managing this program requires about 10 000 engineering and 10 000 equivalent-engineering, clerical people and an expenditure of about $100 million/year for drafting and allied areas. The record keeping associated with this is a complicated job that has not changed basically in 40 years.

A result of this highly labor-intensive activity is that, even with good management, there are cycles and phases when the records are not current. The error rates rise where it is necessary to keep duplicate records. The master copies deteriorate with time whether they are on paper or mylar, and it is difficult to enforce uniformity of record-keeping methods. Furthermore, when records are kept on paper, they are not continuous, and there is a major problem in ensuring that all appropriate sheets are updated when changes are made. Because the engineering work is designed on the basis of these records and there are times when the actual field conditions are different, delays in construction or the restoration of the physical plant can occur, and an inefficient use of personnel and equipment can result. As a result, some engineers maintain private copies of the record at their own level of requirements.

The number of people and the expense that goes into this work have been increasing in recent years. Figure 1 outlines the work flow for the keeping of records of construction work orders.

In the manually kept system, there are at least three redrawings of the appropriate symbology. Each retranscription increases the probability of error, and there is a lengthening lead time when the work load is heavy.

COMPUTER-ASSISTED DRAFTING

A new technology called interactive graphics has emerged in recent years. This uses a combination of devices that are linked together and operated by a computer program. A typical installation has a computer including its software, various peripheral devices, and the interactive-graphics terminals. The computer electronically updates and processes data. It must be fed software, that is, a set of encoded programs of instructions to control its operations. A variety of input and output devices and peripherals can be coupled to the computer: A disk unit can serve as a means of on-line magnetic storage of data, a plotter can transform this data into paper drawings (magnetic tapes can also serve as storage devices for the data and are more readily transportable), and a digitizer can convert information on a paper map or record into an electronically stored record in usable computer language. The graphics terminals are devices to access and interact with the electronically stored record (the data base). These cathode-ray-tube (CRT) terminals can have various characteristics in these systems. They can be local or remote. They can provide only the capability to view the data base, or they can be interactive, i.e., change the data base. They can operate with or without digitizers. The terminal has rapid access to the data base and can provide a visual display of any portion of this data on the CRT. It is also the device through which inquiry and interaction can take place by means of a keyboard and such equipment as a data tablet, a light pen, a thumb wheel, or a stylus. Figure 2 shows a large terminal and its various components.

Compare one of these interactive-graphics systems (Figure 3) with the outside-plant, engineering-record system shown in Figure 1. Once an item is drawn at the interactive terminal, it is stored in the computer either as a part of the data base or as a potential part of the data base that is part of a work order. All kinds of information, both textual and graphic, that a draftsman supplies can be entered from the interactive terminal. At any time, a paper copy of the display on the CRT can be obtained. A pilot installation of this kind of system has been installed at one telephone company. It is a modest experimental effort that will cover approximately 78 km^2 (30 $miles^2$) of fully developed urban area that is served by five telephone wire centers. After a full evaluation, this pilot installation of a larger outside-plant, engineering drafting system will be developed.

This mode of operation has several advantages over the manual mode. The master records on paper and film are eliminated. There is only one copy of the record, and it is in the magnetically stored data base. This method promises reductions in clerical personnel by the elimination of multiple work operations. Individual items need be drawn only once, which means that the drafting of construction work orders and the preposting and final posting of these plant changes on the record data base are accomplished quickly.

Since there are fewer retranscriptions, errors should be reduced. There are obvious economic benefits. Drafting with these systems is estimated to be twice as fast as manual drafting. But, there are more important benefits, such as improved readiness to serve. If records are more accurate and up-to-date, less time is required to search them. Faster repair of failures of large cable is one example of how an accurate up-to-date record can improve service.

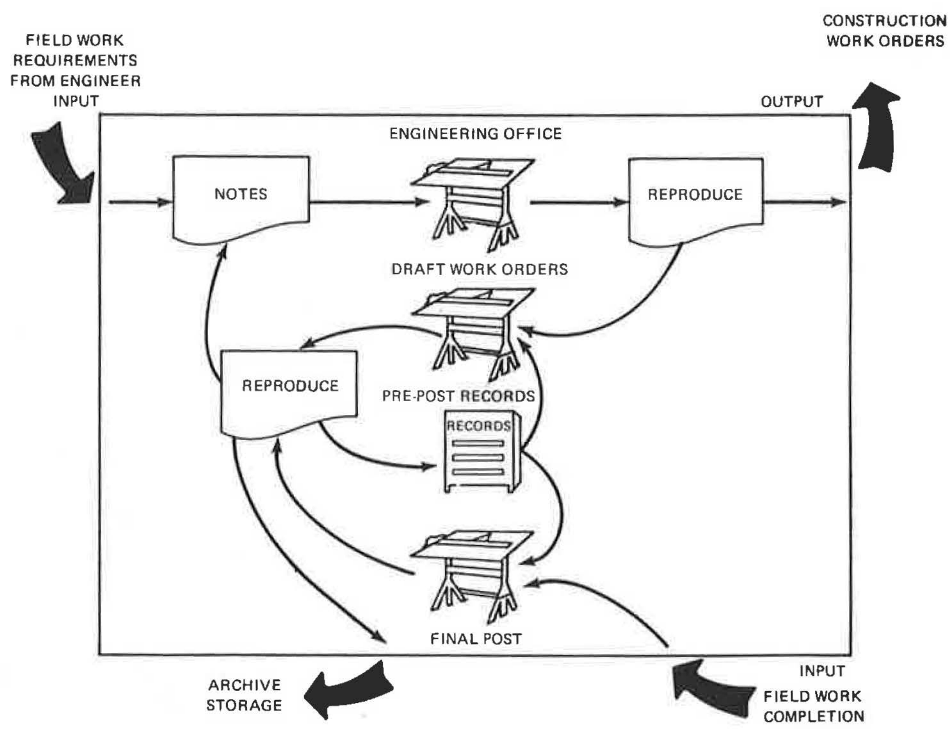
The telephone system is not unique in recognizing the need for improvement in present record-keeping procedures and the impact that this new technology of computer-aided digital graphics can have on operations. It is only typical of many utilities, as this next wave of future shock hits.

In attempts to apply this technology, the major start-up cost is that of the conversion of the existing records to the digitized electronic data base. For example, the records of a typical urban telephone wire center are estimated to require about 6 million bytes when stored in a digitized graphics format. This conversion cost cannot be absorbed in a short period of time by any regulated industry, whether it be telephone, gas, electricity, or a sewer network.

LAND USE RECORDS

Let us consider another application of digital computer graphics that has been developed in recent years. The most widespread application of computer-assisted graphics to geographically based record systems is in the area of land-ownership records. These are map-based records of land parcels, and the related records of ownership, tenure, assessment value, assessment parameters, tax rates, tax-billing data, and such. There are a variety of these systems, most of them quite new, but all of them designed for the primary purpose of supporting tax and ownership records (2). They are all map-based. That is, the data are treated as various overlays to a fundamental map record that is usually restricted to street and property outlines, although occasionally the system incorporates vertical elevation data in the form

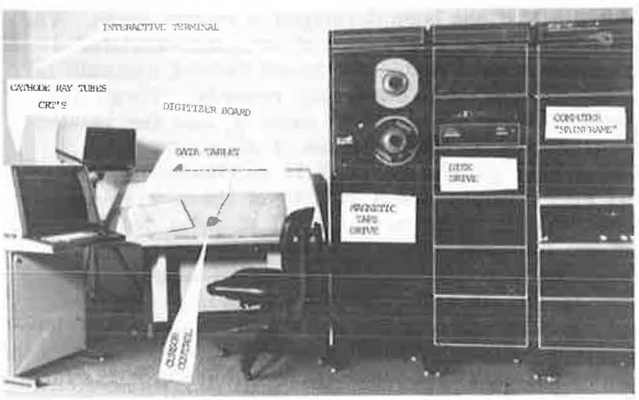
Figure 1. Paper flow without computer.



of contour overlays, as shown in Figure 4. These systems require the same types of equipment and software and provide similar benefits to their users as do the utility-record systems. They also suffer from the same economic problem: The bulk of the cost is that of the initial effort to digitize the map and its information overlays. Thereafter, interactive maintenance is economical because of the reduced drafting cost. However, there is one particular benefit that has pressed developments for land use applications. Consider the experience of the Canadian National Capital Commission. In one small semirural community, the tax rolls were increased almost 20 percent through the effort to overlay against a continuous map, when unassessed properties were discovered and added. This benefit accrues in almost any comprehensive review of a manual record. One of the greatest supervisory difficulties in managing a manual record-keeping system is that of ensuring that record changes are continued from sheet to sheet in the paper operation. This difficulty does not occur in a map-based computer-stored record because the viewer can scan the data base in much the same way that a movie camera can pan a scene.

All of the systems that have been installed have faced this burden of conversion, and several have proposed a community effort. The same map base can be as valuable for utility location, if utility records are overlaid in the data base, as it is for ownership and tax-record location. Once a community has been mapped on a computer, there are many other data about that community that are more readily analyzed or grouped or processed. Examples are demographic data, fire and police-protection coverage, and solid-waste collection. There have been attempts in the past to develop a community of interest and divide the cost of initiating a fundamental map. This is sometimes the point at which a utility becomes interested. At other times, field people have seen opportunities and voluntarily participated in joint computer-assisted mapping projects. None of these have realized the anticipated benefits because none of them have fully addressed optimum user needs in terms of cost. To achieve the savings inherently possible in community projects, there should be some reference standards to allow better value judgments of the anticipated benefits.

Figure 2. Basic interactive-graphics design system.



Note: M and S Computing, Inc., Huntsville, Alabama.

STANDARDIZATION

For many years, utility companies have worked together to solve a common problem, that of the accidental damage to underground facilities by digging operations. The most effective remedy is found in the one-number-to-call systems. Within a region, anyone preparing to dig can call one telephone number for information and assistance in locating underground plant. Over 80 of these systems have been established across the country, many of them under the aegis of the Utility Location and Coordination Council (ULCC) of the American Public Works Association (APWA). These systems require a geographically referenced record. Map-based records are used, and the operation is most efficient if common-base maps are used for all records.

In 1975, ULCC instituted a task force to investigate the impact of computer-assisted mapping systems and the possible benefits of one-number-to-call operations.

Figure 3. Simplified paper flow with computer.

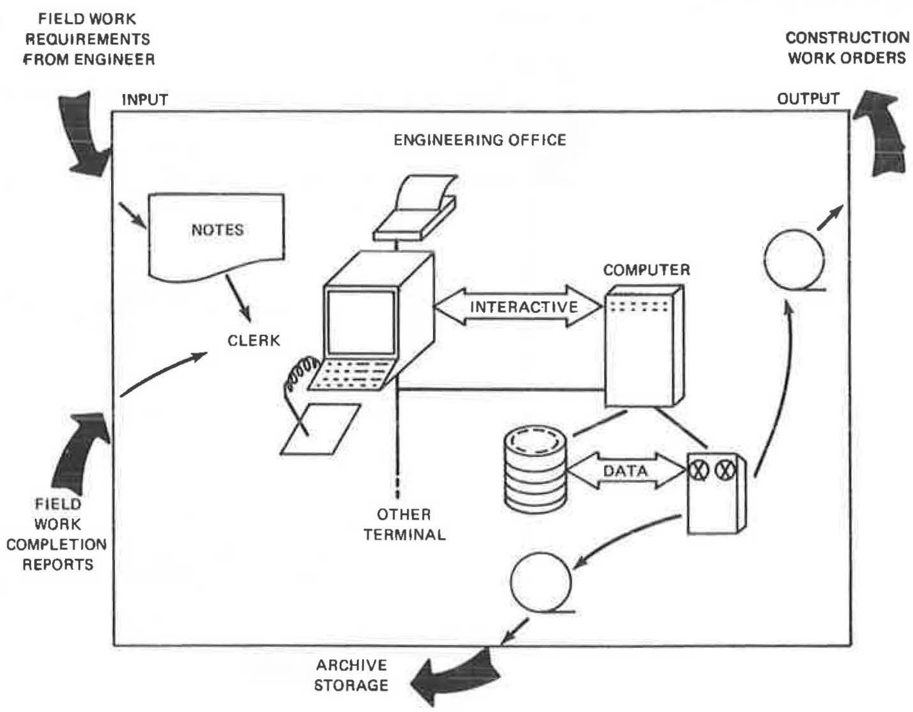
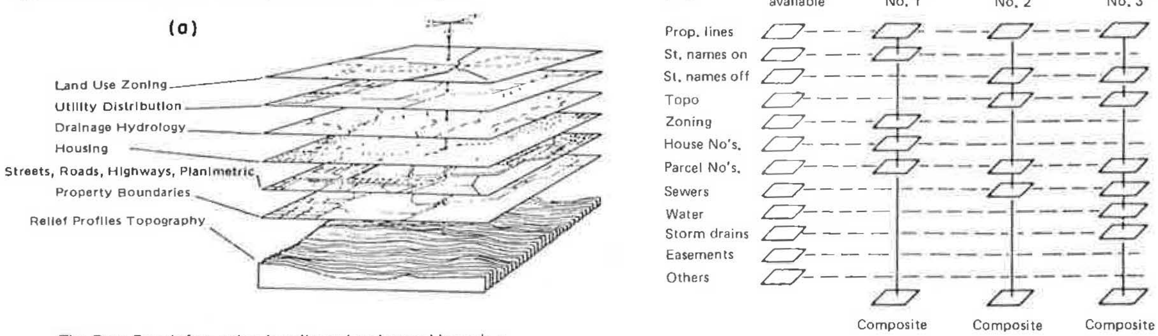


Figure 4. Possible data overlays and search strategies.



The Data Base information is collected and stored in such a way that it may be accessed by subject.

Maps and reports may be computer generated to contain only the information required by the user. Each user has different needs.

Note: Hoskins-Western-Sonderegger, Lincoln.

The report of this task force contained a single recommendation (3). This was that, under the auspices of APWA, there should be a single test-bed installation to establish a joint-use, map-based, computer-assisted system. The project was named Computer-Assisted Mapping and Records-Activities Systems (CAMRAS). The reason given for this single finding was the results of the investigation of existing and proposed systems, which had found that individual choices were made on a one-shot basis and that it was impossible to go back and reconstruct the significant factors leading to choices and decisions. Where local political factors or interdepartmental procedures had been overriding, these could not be subtracted from the conclusions reached. Thus, it was not possible from the experience of present users to construct a basis for technical and procedural standards that would assist future users and planners to evaluate the performance of their own systems and allow some common basis for automatic exchange of data between special-purpose systems and joint-user systems. These are factors that have been generally overlooked in the press of the industry to make sales and of users to improve their record-keeping functions and exploit this new technology. The task-force findings were not critical, but it was felt that there should be some institutional leadership of this new development so that the different systems will have some probability of compatibility. It is also desirable to avoid the wasteful duplication of effort that occurs when individual agencies each evaluate the maze of claims, counterclaims, and experiences of many different existing systems. The existing systems are, in almost all cases, mutually incompatible in the possibility of exchanging or substituting data from one to the other.

Why was government or industry not suggested as the leader here? There are several answers. The existing systems and technology appear to be based on minicomputer capacities that center around local communities or portions of urban centers. There is no national influence by these communities except through an institutional association. On the other hand, the federal government programs are on a national scale and do not provide the fine-grain detail that community systems require. Individual private industry likewise cannot introduce standards except internally, and vendors of all kinds—hardware, software, and services—are making proprietary developments from conclusions based on the experiences of one or two customers at a time. They are, therefore, not in a position to take a broad view to optimize a market. These facts support the conclusion that the leadership should be an institutional responsibility. The potential areas in which standards and procurement specifications or both should evolve from the experience of the test bed are listed below.

1. Operational system standards: (a) data base definition (smallest physical length graphically distinguishable in stored data) and (b) data base content—fundamental records and map content (basic building modules and layers); features and fixtures (e.g., reference grid and its coordinates); facilities, i.e., telephone-utility plant within rights-of-way (visible, subsurface, and vertical location); data base structure [overlay assignments and overlay names (codes), viewing composites and auxiliary views (projections), and capacity]; inputs (data base maintenance) and outputs {hard media, i.e., quality [size, scales, registration error, status (prefile, file, under construction, as-built, and such), notation, and timing rules, overlay content, edge overlap, and reference indexing] and magnetic media, i.e., interface specification (headers; record content, format, and field description; and code)}; hardware performance (computer main frame, peripherals and adjunct memory, interactive terminals, and operator's documentation); software performance [response time (real time and hard copy), operational procedures (e.g., batch versus real time), reliability (recovery-restoration-protection), machine-independent, data-security provisions, overlap provisions, macro commands, high-level source language, and access to source code]; personnel subsystem (skill qualifications and training documentation); and procurement.

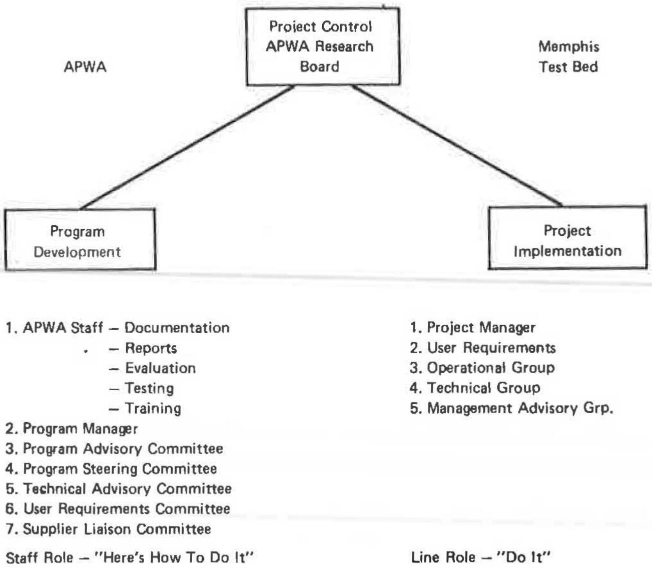
2. Conversion (manual to automated) system standards (i.e., initial digitization): (a) outputs final—all data base specifications above apply; (b) facility map(s)—source qualifications and encoding (record reliability); and (c) procurement—translation of operational system standards for impact.

3. Photogrammetry standards: (a) map base—composition and size, definition, and distortion tolerances and (b) procurement—translation of operational systems and conversion standards for impact.

4. Aerial photography: (a) synchronization of ground-reference survey including monuments, facility targeting, and flyover and (b) procurement—translation of operational system, conversion, and photogrammetry standards for altitude, area, and picture quality.

The test-bed operation will be managed as an individual community operation with an advisory staff of participating members of APWA and the support, for standards development, of the APWA staff (Figure 5). This effort should lead to standards that will assist

Figure 5. CAMRAS organization.



Note: APWA, Chicago.

utilities and public-works agencies in their participation in one-number-to-call utility-location systems, to procurement guidelines for future users, and to guidelines for the establishment of a joint-user system.

Therefore, to the advantages of computerized mapping, we now add the benefits of standardization. With standardization, we add the capability for computer-to-computer exchange of data, which implies compatibility with private records systems. Vendor performance is clarified because the entire procurement process is simplified. Procurement documents that have clear performance standards will focus vendors' developmental activities, and a better evaluation can be used to justify vendor selection. Perhaps in summary of all of the above: For all future users, the experimental risk is reduced.

Governments at all levels profit from the existence of widely accepted standards. One small example is that the fine-grain, ground-control networks of local municipalities can be more readily referenced to a national network through computer-controlled conversion systems. Those who are interested in land records, including surveyors, particularly benefit by standards for reference and recording. Conveyors, agents, and legal representatives are more assured by standard descriptive systems. Insurors are more certain of the permanent existence of parcel descriptions and parcel-adjacency references. Therefore, the courts benefit because there is a reference method in the computerized standard-recording procedure that can be compared to the methods of the case in hand. Buyers and sellers of land are more readily assured of the conveyance records. Permit agencies and recorders of rights-of-way, contractors, and designers and engineers are more assured that their records are mutually compatible with those of others whom they may affect (and who may affect them). Finally, utilities are more assured that the locations of their systems are reliably referenced. However, with the daily installation of new systems, the ability of those already involved to adjust to a reference standard is constantly being reduced. With each new system that is installed, it becomes more difficult to promulgate a generally accepted benchmark standard. AWPA is unique in that the needs for and benefits from these standards cross the full spectrum of its membership.

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Eliminating Vehicle Rollovers on Turned-Down Guardrail Terminals

T. J. Hirsch and C. E. Buth, Texas Transportation Institute
John F. Nixon, David Hustace, and Harold Cooner, Texas State Department of Highways and Public Transportation

A relatively simple method has been found to modify the turned-down ends of highway guradrails to eliminate or minimize the probability that a vehicle impacting them will ramp and roll over. To modify the standard guardrail, the $\frac{5}{8}$-in diameter bolts are removed from the first five posts. With these bolts removed, the rail will drop to the ground if the turned-down terminal section is struck by a vehicle, which eliminates ramping of the vehicle. To hold the rail at its proper height [69 cm (27 in) in Texas] before and during a vehicle impact along the length of need, backup plates are bolted to the first five posts. The action of this modified guardrail terminal is simple. When a vehicle tire or bumper pushes down on the turned-down terminal, the rail drops from the first five posts, which allows the vehicle to pass over the rail. If the vehicle bumper impacts the rail on the length of need and pushes it laterally against the backup plates on the posts, the rail is held at its proper height and the vehicle is redirected. The test program included the four crash tests for longitudinal barrier terminals. All of the tests were successful, and no vehicles rolled over.

The steel flex-beam W-beam guardrail is used extensively on highways. In the late 1950s and early 1960s, the dangers of guardrail ends became apparent after