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# The AULT System

**Automatic location and identification system has been developed to inventory, measure, and record information for transportation and land development study.**

## INTRODUCTION

MODERN LONG-RANGE STUDIES of transportation and land development are interdisciplinary engineering-socio-economic investigations. One facet of such studies is a detailed inventory, analysis and forecast of land uses in so-called urbanized areas as a basis for land development and transportation planning. Where no satisfactory information is available from secondary sources, hundreds of field workers are first sent out to list the uses of every piece of land and of every floor space in every building. This includes every business, residence and other establishment. When this mass of information has been collected, it must be correlated and compiled with the following items of data among others: the area measurement of every block and of every land parcel in each block; floor area measurements for non-residential buildings; the measured grid coordinates of every block; and identifying information such as census tract and block number, geographic subdivision, city, county, and state.

In land development and transportation studies prior to the one with which this paper is concerned, the area and grid coordinate measurements were made with the aid of hand tools such as scales, planimeters, grid templates, parabolic templates, random dot templates, etc. The data were handwritten on paper forms and later key-punched on cards. These procedures were redolent with errors which were undetectable; and the magnitude of the task can be seen from the fact that, for example, 48,000 blocks were included in the recent Penn-Jersey Transportation Study covering the Philadelphia-Camden-Trenton metropolitan complex.

The task became still more formidable in the transportation study with which this paper is concerned, namely the study of the Tri-State Transportation Committee. This Committee is a government agency established in 1961 jointly by the governors of the States of New York, New Jersey and Connecticut, and contains representatives of state and local government agencies. The Committee operates with the support and cooperation of the U. S. Bureau of Public Roads, the U. S. Housing and Home Finance Agency,

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and the Federal Aviation Agency. The Committee is conducting short and long range studies of all forms of transportation (including automotive, rail, ship and air) in a region of 8,000 square miles in and around the New York City metropolitan area, including large areas of New Jersey and Connecticut. This region contains 5,000 urbanized square miles of which a detailed land use inventory must be made, including approximately 180,000 blocks and 2,000,000 land parcels. This is the largest transportation study ever undertaken.

Automation is needed in this task, which is similar to tasks being faced by large transportation studies in other parts of the United States. Recognizing this, the Tri-State Transportation Committee retained the consulting firm of Paul Rosenberg Associates to study the automation problem, recommend a solution, and assist in developing the necessary equipment and system. A survey of commercially available equipment and a canvass of equipment and systems under development in government and industrial laboratories uncovered no system that met Tri-State's requirements satisfactorily. The AULT System and AULT components, described below, were therefore designed and developed by PRA and Tri-State. AULT (pronounced as the last three letters in the word "salt") was originally coined by PRA and Tri-State to stand for Automatic Locational Table. AULT was subsequently used to designate the entire AULT System, described below, including its three principal components, the AULT Reader, the AULT 526, and the AULT Plotter.

Tri-State, with PRA's assistance, has constructed two full AULT Systems, including two AULT Readers, two AULT Plotters, and three AULT 526's, all to PRA-Tri-State specifications. The contractors for the components were: AULT Reader, Itek Corporation, Waltham, Mass.; AULT Plotter, Keuffel & Esser, and Electronics Associates, Inc., Long Branch, New Jersey; AULT 526, International Business Machines Corporation. Almost all of the electronic components in the AULT System are solid state.

ABSTRACT: *The AULT System has been designed, developed and used successfully for the following purposes: to measure semi-automatically and with high speed the grid co-ordinates of large numbers of points of interest on area displays of information, such as aerial photographs, photomosaics, maps and charts; to record these locational data automatically and rapidly on punched cards for later transference to magnetic tape for digital data processing, including the computation of areas of land parcels and blocks; to record concurrently descriptive information such as state, county, city, geographic subdivision and census block number. AULT has been developed by the Tri-State Transportation Committee (New York, New Jersey and Connecticut) and Paul Rosenberg Associates to "locationally identify" and measure the areas of land parcels and blocks for land use inventory, analysis and forecast, as a part of the largest transportation study ever undertaken. The urbanized part of the study area covers approximately 5,000 square miles and contains an estimated 2,000,000 land parcels in 180,000 blocks. The use of AULT is also being extended to inventories of transportation facilities such as arterial highways and expressways, bus routes, subways and railroads.*

ALISP, a more elaborate system than AULT, was also devised during the course of the PRA-Tri-State system study, but was not instrumented because of its higher cost. ALISP stands for Automatic Locational Identification Symbol Placement.

## AULT Components

### AULT READER

The AULT Reader (Figure 1, page 844) contains a translucent diffusing glass platen, 42×43 inches, in a vertical plane, on which aerial photographs, photomosaics, maps or charts can be mounted and oriented. The platen is provided with back and front illumination systems, the intensities of which are separately adjustable by the operator so as to accommodate all types of opaque, translucent and transparent copies. Almost the entire area of the platen is visible to the operator at all times; (the kickboard between the

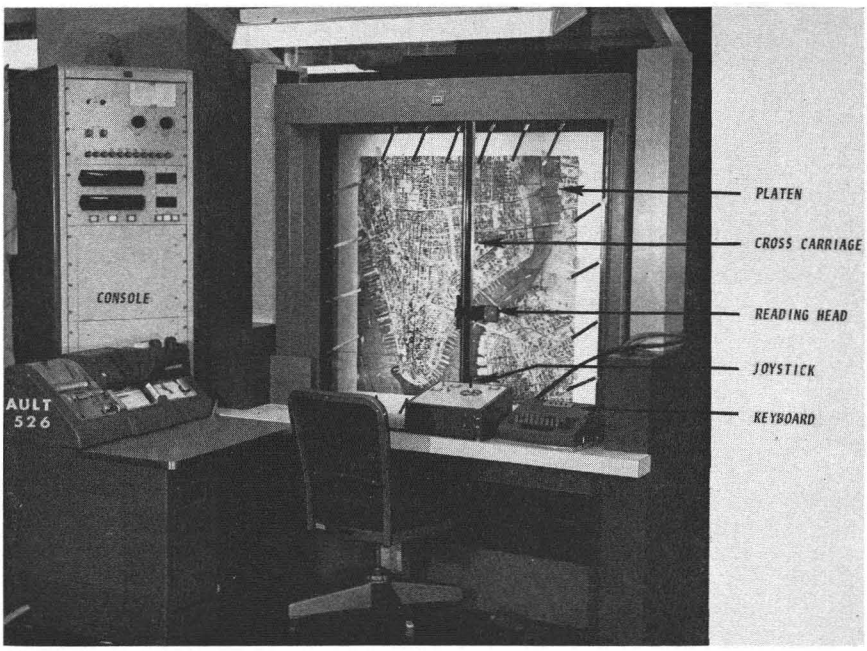


FIG. 1. AULT Reader and 526. AULT Plotter is to right of the Reader but is not shown in this photograph. (See page 843)

seated operator and the platen is transparent). The platen is raised and lowered by a motor drive, controlled by the operator through a toggle switch on his control panel so that he can adjust any area of interest to his eye level when seated before the AULT Reader.

The operator examines the area of immediate interest with a reading head upon which he can mount one of several interchangeable viewing devices, i.e.: a transparent plastic cursor with an inscribed cross hair, which can be depressed to touch the photograph or map surface to eliminate parallax; a double cursor consisting of two sets of cross hairs through which the operator may sight to eliminate parallax; a swing-out simple magnifying lens for use with the single or double cursor; a small projector which projects the image of an illuminated cross hair reticle onto the photograph or map in a direction normal to the platen, thereby eliminating parallax even with opaque pasted-up maps of varying thickness (e.g. Sanborn-type original maps); a low power microscope and cross hair, with variable magnification up to $7\times$. The single cursor with magnifying lens, and the projected reticle, are used most frequently in Tri-State's work. The microscope is useful for periodic checks of the accuracy of the AULT Reader, and for making measurements on high resolution photography with the full precision and accuracy of the AULT Reader.

The reading head, carried on a cross-carriage, is moved by servo motors in a vertical plane parallel to the platen along mutually orthogonal $X$ and $Y$ directions. Speeds and directions of the $X$ and $Y$ motors are controlled by a joy-stick which springs back to a neutral center position when the operator releases it. When the stick is in its center position, the reading head is motionless and is locked in position. Inclination of the joy-stick in any direction away from center causes the reading head to travel in the corresponding direction with a speed that varies directly as the amount of the inclination. The operator thereby "flies" the reading head over the platen. He can select either one of two speed ranges by a toggle switch; a "scan" speed range up to approximately 0.1 inch per second, for fine setting of the reading head; and a "slew" speed range up to approximately 4 inches per second.

The $X$ and $Y$ coordinate positions of the reading head are measured automatically and continuously in the AULT Reader, and are displayed to the operator at all times in decimal numerals by two rows of six nixie tubes each, mounted in a chassis adjacent (Figure 2) to the AULT Reader. The coordinate values are measured in statute miles ac-

cording to one of the following three scales at the choice of the operator: one inch on the platen equal to 50 ft., 400 ft., or 2,000 ft. (Other scales are also available by modification of the circuitry.) Each of the $X$ and $Y$ decimal displays read from 000.000 to 999.999 miles, in a grid coordinate system established by Tri-State.

These $X$ and $Y$ coordinate values are also continually available in the AULT Reader in digital form. When the operator has set the reading head cross hair on a point of interest, he presses a record command button located conveniently alongside the joy-stick, (or, if he prefers, he may depress a foot-pedal switch on a flexible cable which transmits the same command). The record command places the digitized $X$ and $Y$ coordinate values into a buffer storage within 15 milliseconds, and immediately transmits these digitized values to the AULT 526 for recording on punched cards. The buffer storage speeds up the operation by permitting the operator to start moving the reading head to the next point he wishes to locationally identify, only 15 milliseconds after he has pressed the record button, without waiting the approximately 750 milliseconds required for the 526 to punch the coordinates into a card.

The following are the attained accuracy, precision and sensitivity of the coordinate measurements and of their digitized outputs in miles at all scales over the entire usable area of the platen: accuracy (absolute), plus or minus 0.03 inch; precision (reproducibility or resettability), plus or minus 0.003 inch; sensitivity (least count), 0.003 inch.

### AULT 526

The AULT 526 component (Figure 1) is an IBM 526 summary card punch modified to perform the particular functions required by the AULT System, and to operate compatibly with the AULT Reader and the AULT Plotter. The punching station in the AULT 526 receives its punching information from the AULT Reader and an attached IBM alpha-numeric keyboard, not from the 526 reading station as is customary with this summary card punch. The reading station is used to read and transmit instructions and coordinate values to the AULT Plotter, independently of the AULT Reader operation. Coordinate values are received by the 526 from the AULT Reader, recorded in a punched card at the punching station, and then transmitted to the AULT Plotter a few seconds later when that card passes through and is read at the 526 reading station. The

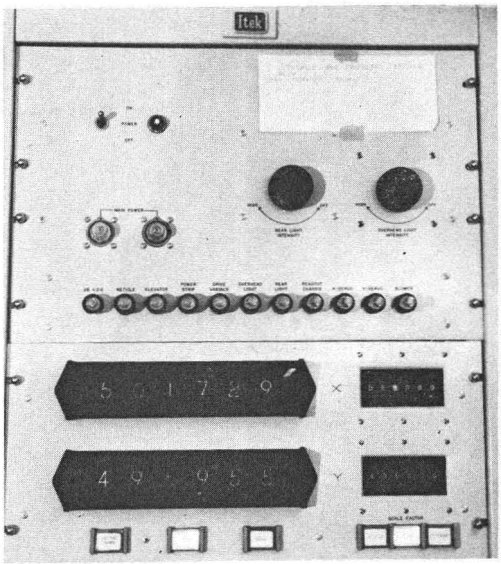


FIG. 2. Close-up of top of AULT Reader console, displaying $XY$ coordinate values and various controls.

operation of the AULT Plotter is therefore said to be concurrent, rather than simultaneous, with the AULT Reader operation. This serves as a check on the reliability of the recorded information, because the AULT Plotter displays what has actually been recorded on the cards. This design also permits unambiguous and rapid diagnosis of the cause of any electronic, mechanical or electromechanical trouble which may arise in the system's operation, because the operations of the AULT Reader and AULT Plotter can be isolated from each other at the AULT 526 interface.

Cards on two program drums, which are provided in the 526, can be changed to establish a wide variety of punched card formats, interspersing the automatically punched $XY$ coordinate values with alpha-numeric information punched by the operator via his keyboard, in patterns dependent upon the particular AULT operation being performed. Up to four formats are available at the option of the operator by keyboard selection of four program levels, without changing the program card. Alpha-numeric information can also be emitted or duplicated in desired columns automatically, thereby saving the operator's time when items of information or plotter instructions must be repeated in successive cards.

### AULT PLOTTER

The AULT Plotter component (Figure 3) of the AULT System is an automatic plotter

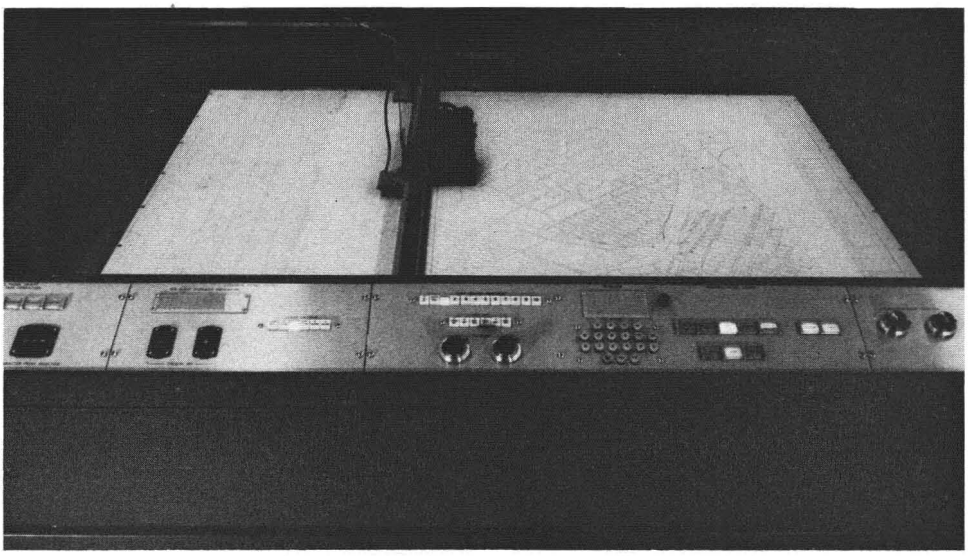

FIG. 3. AULT Plotter.

with a horizontal plotting surface and a usable plotting area of approximately 40×60 inches, accommodating paper or plastic sheets up to about 48×60 inches held by vacuum. The plotting surface is 12 inches from the floor, so as to be visible to the AULT operator who is seated at the AULT Reader. Plotting is done by an 8-pen turret and a 48-character alpha-numeric symbol printer with adjustable orientation. Selection and operation of the printing symbols and of the pens (for different colors and line widths) are under automatic program control of the punched cards which are read in the AULT 526. The punched cards control also the selection of one of five modes of operation of the Plotter, namely: plotting individual points; plotting straight lines automatically between any two points, the coordinates of which are given to the Plotter by the punched cards; plotting alpha-numeric characters; no operation; and standby of the plotting head at one end of the plotting board. The operator may also command the plotting head to go to its standby position at any time by actuating a switch on the AULT Reader control panel, to allow an unobstructed view of the plotting area. The Plotter can also be commanded to print a block of two rows of five digits each (e.g. representing $X\,Y$ coordinate values) at a location with a fixed offset from a commanded coordinate value; this feature can be used to print the $X\,Y$ locational identification of a block automatically in the open area inside the block when the identification point is one corner of the block.

The attained accuracy and precision of plotted points, lines, and characters, over the entire plotting area, are: accuracy (absolute), plus or minus 0.03 inch, including cumulative errors; precision (reproducibility), plus or minus 0.015 inch.

The Plotter receives its commanded coordinate values from the AULT 526 in six digits in $X$ and six digits in $Y$, each representing values from 000.000 to 999.999 miles in the Tri-State grid coordinate system. These six-digit coordinate values are displayed continuously and automatically in binary coded decimals on the AULT Plotter console, although the area represented by the Plotter in a plot at any one of the three scales of the AULT Reader (one inch equals 50 ft., 400 ft., or 2,000 ft.) is far less than the 999×999-mile domain. The operator can set the lower left corner of the plotting area to any arbitrary $X\,Y$ value in this domain, in any one of five scales (one inch equals 50 ft., 400 ft., 2,000 ft., 2 miles, or 4 miles). Thereafter, the AULT Plotter plots automatically in all its modes throughout its plotting area at that scale, without any resetting by the operator, even though the plot crosses ambiguous coordinate values (e.g. from 499.999 to 500.001 miles).

One of the AULT Plotters has been designed and built to operate with magnetic tape as well as punched cards.

## SYSTEM OPERATION

The AULT System is flexible in that its operational procedures can be changed and

adapted to a variety of uses with aerial photographs, photomosaics, maps and charts. One example of an AULT System operation is described below. This particular procedure has been used successfully for locational identification and land use inventory purposes. The individual coordinate values of more than 1,500,000 points have been read, recorded automatically and processed by computer, in this AULT operation.

It is conservatively estimated that the AULT System has performed this task in one-tenth to one-twelfth of the time that would be required to do the same thing with the same accuracy by hand methods. Even if the hand methods were used at lowest acceptable accuracy, the AULT System would still perform the task at its built-in high accuracy in one-seventh to one-ninth of the time required by hand methods.

An annotated translucent photomosaic is mounted in the AULT Reader and oriented by the operator so that the gridlines on the mosaic are parallel to the $X$ and $Y$ coordinate directions of motion of the AULT Reader. The operator checks this orientation (Figure 4) by setting the cross hair on an $X$ gridline near one edge of the sheet, and slewing the cross hair, in the $Y$ direction only, to the other end of the sheet where the cross hair should fall accurately on the same $X$ gridline if the sheet is properly oriented. The line-up is checked further by performing an analogous operation with one or more $Y$ gridlines.

FIG. 4. Operator seated at AULT Reader looking through reading head at point on photomosaic, with left hand operating the joy-stick of the control box and right hand on the keyboard.

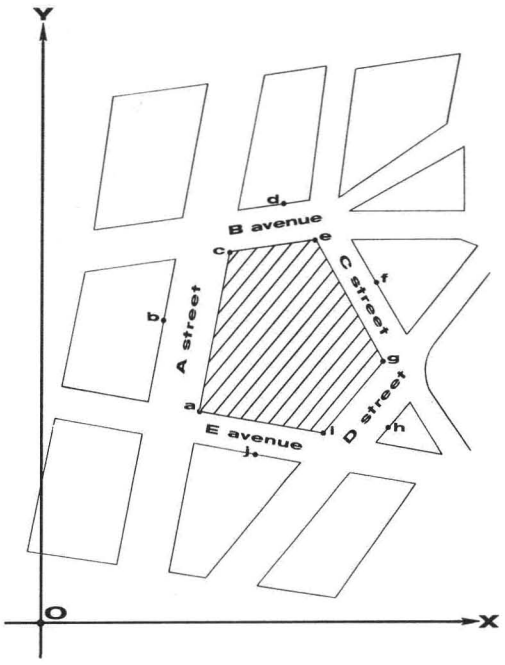


FIG. 5. Sketch used in describing the operation of the AULT system.

The operator sets the cross hair on some convenient intersection point of the $X$ and $Y$ gridlines (O in Figure 5). Using the numerical thumbwheels on the AULT Reader console, the operator sets into the AULT Reader the $X$ and $Y$ values of that grid intersection (in miles, at some value between 000.000 and 999.999).

The operator is now ready to read points and record coordinates and other locational identifications, by proceeding as follows. The operator sets the cross hair at the southwest or most southwesterly corner of the block or area (point $a$ in Figure 5). The $X\,Y$ coordinates of this point become the permanent identification signature of the block. The operator presses the record button (or foot switch) thereby automatically transmitting the $X\,Y$ coordinates for point $a$ into a punched card.

The operator moves the cross hair to any convenient point $b$ on the property line across the street, proceeding around the block in a clockwise direction. He presses the record button to record the $X\,Y$ coordinates of this point on the punched card. At this point the operator keypunches in the street name or a code number for it (A Street in Figure 5).

The operator slews to the next corner $c$ of the block and records the coordinates auto-

matically. Then he slews to point *d* on the boundary across the street and automatically records the coordinates.

The operator continues this sequence of operations around the block, regardless of the number of sides of the block, until he returns to the south-west corner *a*, where he started. This second measurement of the coordinates of point *a* is compared with the initial reading in a later computer operation which rejects the measurement of this block if the difference between the two readings is not within tolerance.

The operator then repeats the same procedure for all the other blocks on the photomosaic. If parts of the perimeter of the block or area are curved, the operator approximates the curved perimeter or boundary by a series of two or more straight lines, treating the ends of these straight lines as though they were corners. He never has to track along any line, straight or curved. From the *X Y* coordinates of the points alone, the computer computes block areas, street areas, street widths, street lengths and block perimeter.

The operator need keypunch state, county and minor civil division codes only once within a minor civil division. This information is punched into a header card, and the computer inserts the information into every block record on magnetic tape. The equipment and its operation are designed to maximize the speed and efficiency with which the operator accumulates essential data only, with no redundant coordinate measurements or redundant alpha-numeric descriptive information.

The AULT Plotter, operating on line with the AULT Reader and 526, continually monitors the operator and provides him with a self-check as to which blocks are completed, which block should be done next, and even which block corner or block side he is working on at any moment. The AULT Plotter does this by automatically drawing the straight lines of the block sides between the corner points of the blocks as rapidly as the operator moves his cross hair from point to point. The plot is always in full view of the operator at his side.

### Acknowledgments

The following members (listed alphabetically) of the technical staff of Tri-State Transportation Committee have participated and assisted in the development of the AULT System: Geoffrey J. H. Brown; Dr. J. Douglas Carroll, Jr., Executive Director; Donald J. Clark; William Harting, Jr.; John S. Hirshout; William L. Mertz, Technical Director; Edward F. Sullivan.

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# ERRATA

(*Continued from page 841*)

IN THE MEMBERSHIP LIST beginning on page 661 of the July 1966 issue, the following entries should read:

Park, W. Sidney, Park Aerial Surveys, Louisville, Ky.—Pres.; Emeritus Member.

Turpin, Richard B., Box 524, Bedford, Va.—Dept. of Civ. Engr., Univ. of Wis., Madison, Wis., Assoc. Prof.

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