AN INTERACTIVE FACILITY FOR THE MODIFICATION AND UPDATE OF DIGITAL RADAR LANDMASS SIMULATION DATA

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Radar landmass simulation for training until very recently was implemented using data stored on a film plate and transmissively read by a CRT/photomultiplier arrangement. These systems, typified by the AN/APQ-T10/T11 trainer built for the USAF, have the basic limitation that the data is not easily modified or updated. The generation of a new film plate can take six months.

With the advent of new digital memory technology it has become practical to store radar landmass data digitally and produce video by means of special digital processing.

One of the most significant advantages to an all-digital system is the fact that the radar landmass data can be changed. Update from new cartographic information to incorporate the latest and most accurate radar-significant information and to correct previous errors is easily accomplished in an all-digital system, and presents the most compelling reason for having such a system. A second reason is the ability to selectively delete or modify targets and navigation checkpoints, either in a real tactical situation or as a training exercise.

The ease and efficiency with which digital radar data can be modified depends on the device employed to do the work. With as little equipment as a teletype, a minicomputer, and a tape or disc drive, it is possible to produce radar data modification. On the high end of the efficiency (and price) scale is a real-time digital radar landmass simulator (DRLMS) with an interactive facility for data modification. Such a system has been built for the F-4F and F-4E Weapon System Trainers and is the subject of this paper.

The interactive update facility is attached to a DRLMS system configured to simulate the AN/APQ-120 radar set. The major functions of the DRLMS as well as the interactive update facility are depicted in Figure 1. The DRLMS system has software and hardware devoted to moving selected data from a 1250 x 1250 NM gaming area to a small, fast core memory for further processing into radar video and also provides data retrieval capability for the interactive update facility.

The elements in Figure 1 which enter into the update process are the regional, district, and sector memories; the computer control system; and the update video processing system. The regional memory is comprised of three moving head disc drives, each having a capacity of 4×10^8 bits. The district memory is a fixed-head disc with a 5×10^7 bit capacity. The sector memory consists of four banks of core, two banks of 8,000 32-bit words and two banks of 8,000 48-bit words. The computer control system contains two minicomputers with paper tape readers, a magnetic tape unit, and a teletype. Update video processing and display consist of special digital hardware, displays, and operator controls in an integrated console. A photograph of the console is shown in Figure 2. An accessory to the console (not shown) is an X-Y digitizing table having 0.001-inch resolution with 0.005-inch accuracy.

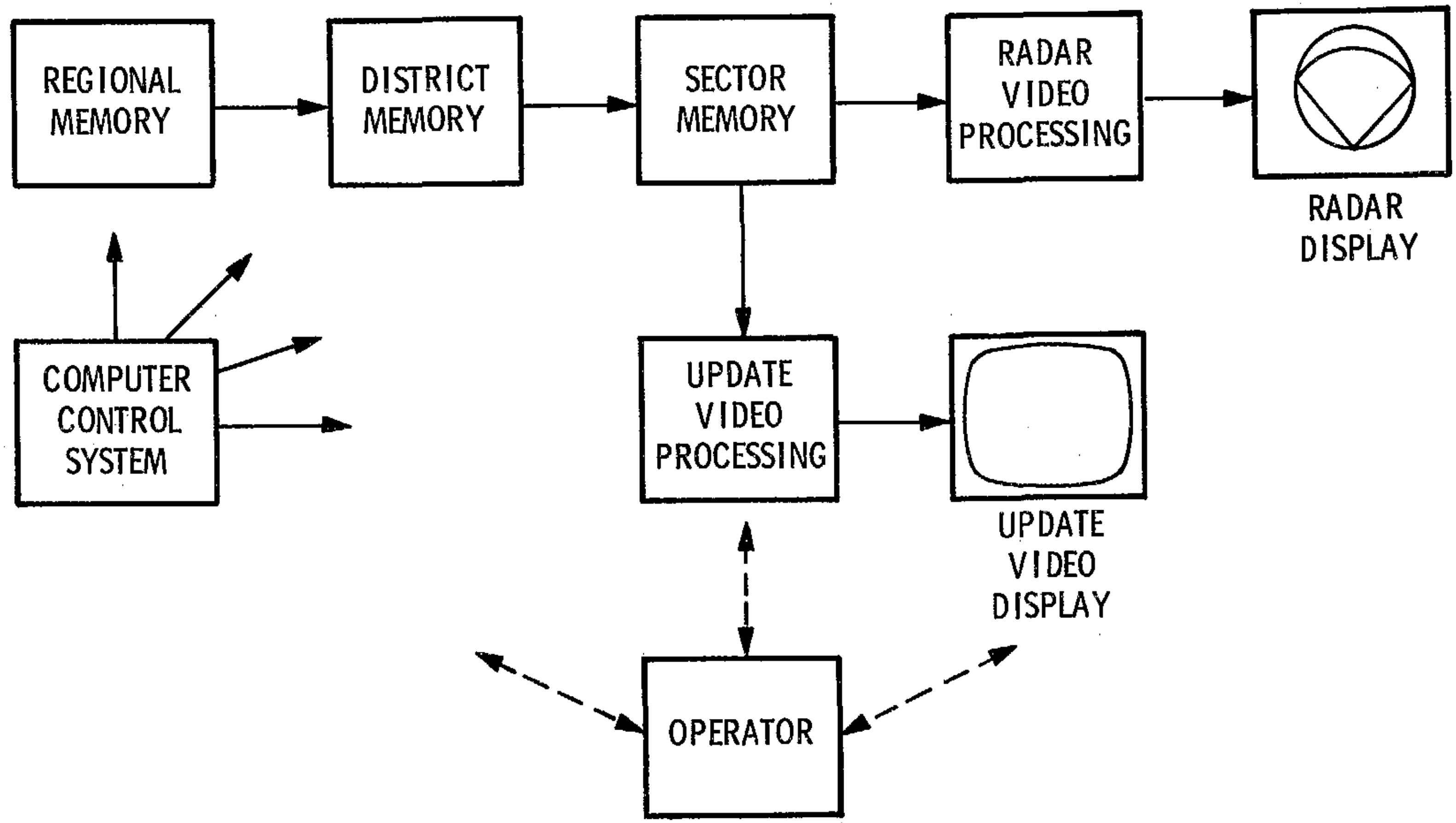

Figure 1 DRLMS SYSTEM WITH INTERACTIVE UPDATE FACILITY

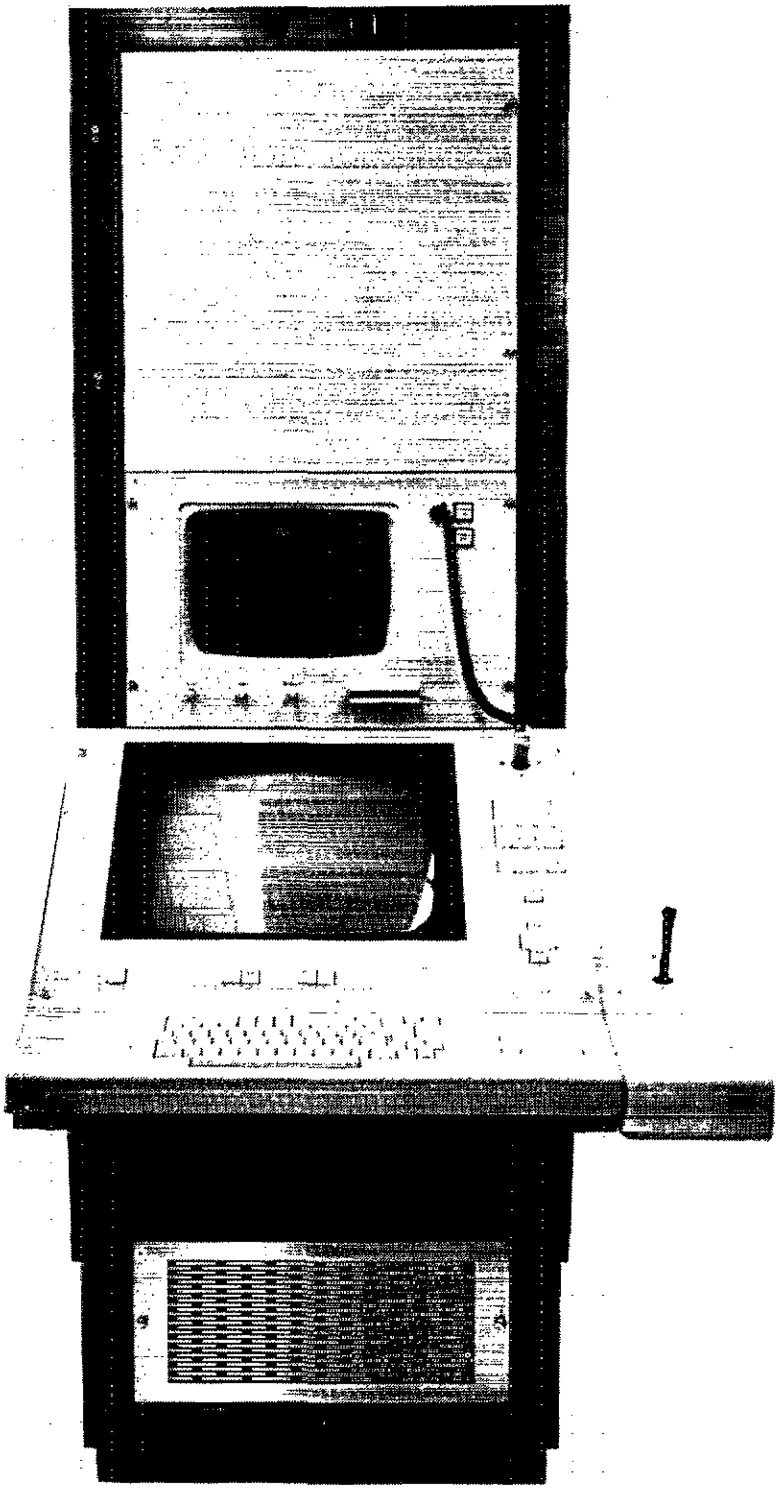

Figure 2 OPERATORS CONSOLE FOR INTERACTIVE UPDATE

During an update sequence, the control computer system moves data from regional memory to district memory and from district memory to sector memory as though it was providing data for radar video. During normal simulation, the regional memory contains the entire data base, or gaming area, the district memory contains the data within radar range of the aircraft, and the sector memory contains data immediately surrounding antenna azimuth. For update, however, the sector memory is formatted so that it can cover a rectangular display rather than a sector of radar scan.

It then functions as a refresh memory for the update console data display. The operator directs this data transfer and display and observes and corrects or changes the data as required. Blocks of modified data are accumulated in district memory and are immediately available for display to compare modified and unmodified data. When the update task is completed, the operator directs the system to incorporate the new data into regional memory, after which it may be displayed as a radar return via radar video processing.

To understand the detailed data modification procedures for this system, it is necessary to examine the form of the data. The DRLMS data is stored on X-Y Cartesian grids in two forms, radar reflectance and terrain elevation. Each point on the grids has an assigned value. The data is stored at several different resolutions to accommodate different radar range settings. Reflectance codes are 3-bit numbers which in real-time radar simulation are assigned reflectance levels ranging from 0 (water) to 255 (bright culture). Terrain elevations use 8-bit numbers having a variable scaling such that a range of elevations from sea level to 17,500 feet are represented. The grid is taken from an analog RLMS film plate so that geodetic latitude and longitude are related to grid coordinates by the mapping equations for a Lambert Conic Conformal projection with two standard parallels. With the understanding that DRLMS data is a grid of values for reflectance and elevation, the following paragraphs describe the physical features of the interactive facility.

The operator's console has features which allow the display, identification, and modification of elements of the data grid. These features are listed below. Their physical arrangement is as shown in Figure 3.

1) Data Display - The data display is a CRT capable of displaying 1024 raster lines modulated to 8 shades of gray. It is rectangular with a 17" diagonal measurement. Scan is interlaced 2:1 with a vertical rate of 50 fields/second.

2) Function Switch Panel - The function switch panel contains switches for the following functions:

   a) Reset
   b) Display Elevation/Reflectance
   c) Compare Old/New
   d) Aperture Selection Matrix
   e) Cursor On/Off
   f) Light Pen On/Off

3) Keyboard and Alphanumeric Display - The alphanumeric display is a small CRT having its own refresh memory and character generator capable of displaying 10 lines of 32 characters each. Characters may originate from

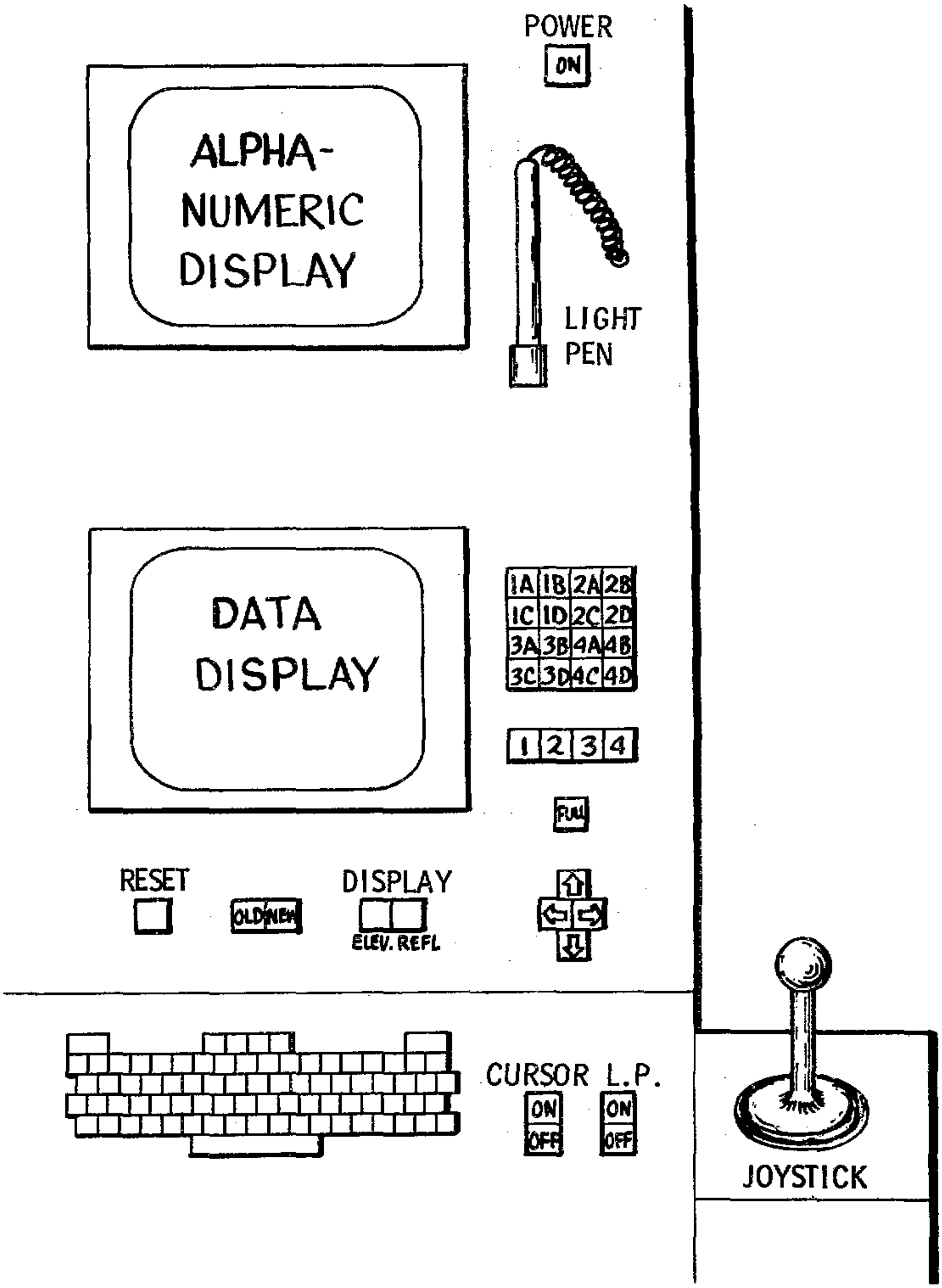

Figure 3   F-4F AND F-4E UPDATE CONSOLE OPERATOR'S CONTROLS AND DISPLAYS

the console keyboard or the computer. The displayable characters are a subset of ASCII standard characters, and match those available on the keyboard. Both keyboard and alphanumeric display interface to the computer.

4) Joystick - The joystick provides means of positioning an electronically generated cursor on the data display. It is of the isometric rate type; that is, the rate of cursor movement in any direction is proportional to the force applied to the device.

5) Light Pen - The light pen is capable of sensing the raster on the data display as it paints each data point. Signal processing and control logic derive the pen's position in terms of the displayed data for computer input.

The central element of the operator's console is the data display. The data display exhibits a square matrix of shaded squares to represent the relative magnitudes of 3-bit reflectance data or 8-bit elevation data. Since only 8 gray shades are available, elevation data is viewed through an 8-level "window" derived from the 256 possible levels in the 8-bit code. The elevation window is specified by keyboard input. The input consists of a base elevation in feet followed by a resolution increment to the nearest available level in the data, e.g. base = 1750 feet and increment = 25 feet becomes base = 1700 and increment = 50 feet since the LSB of elevation data is 50 feet above 1600 feet. In this instance, all elevation below 1700 feet and all elevation above 2050 feet would be displayed black. The intermediate values would be displayed as shades of gray. An example of such a display is shown in Figure 4. The area shown is near Phoenix, Arizona. An input of increment = 0 results in display of the base elevation points only as a contour or contours of constant elevation. Reflectance data is displayed throughout its 8-level range. An example of a reflectance data display is shown in Figure 5.

The number of data points displayable for each data resolution group in regional memory is shown in Table I. During light pen operations the center of each shaded square representing a data point is brightened to assist the operator in finding points and to enable the light pen to function precisely. Light pen operations are restricted to apertures of 64^2 points, and 250-foot and 1,000-foot data bases. The cursor appears on the display as a bright cross inserted in the video and is positionable to the centers of reflectance data points for both reflectance and elevation displays. The data display is refreshed by repetitively reading the contents of sector memories.

The keyboard and alphanumeric display are used to communicate with the computer in a manner similar to a teletype machine. Commands entered in the keyboard appear on the character display, and computer responses appear as messages on the character display. Commands are those functions not incorporated in the function switch panel.

The light pen is used only when updating data. It is pointed at points on the data display either individually or in connected sequences to identify points, lines, and areas to be modified. The kind of modification to be made is specified by keyboard input. The light pen function and center point brightening on the data display are enabled with the function switch Light Pen On.

Figure 4 ELEVATION DATA DISPLAY

REFLECTANCE GRID (FEET)	ELEVATION GRID (FEET)	REFLECTANCE DISPLAY (POINTS)	ELEVATION DISPLAY (POINTS)	AREA DISPLAYED (N.M.^{2})
250	1000	64^2	16^2	2.625^2
250	1000	128^2	32^2	5.25^2
250	1000	256^2	64^2	10.5^2
500	1000	64^2	32^2	5.25^2
500	1000	128^2	64^2	10.5^2
500	1000	256^2	128^2	21^2
1000	4000	64^2	16^2	10.5^2
1000	4000	128^2	32^2	21^2
1000	4000	256^2	64^2	42^2
2000	4000	64^2	32^2	21^2
2000	4000	128^2	64^2	42^2
2000	4000	256^2	128^2	84^2

Table 1 TABLE OF APERTURES

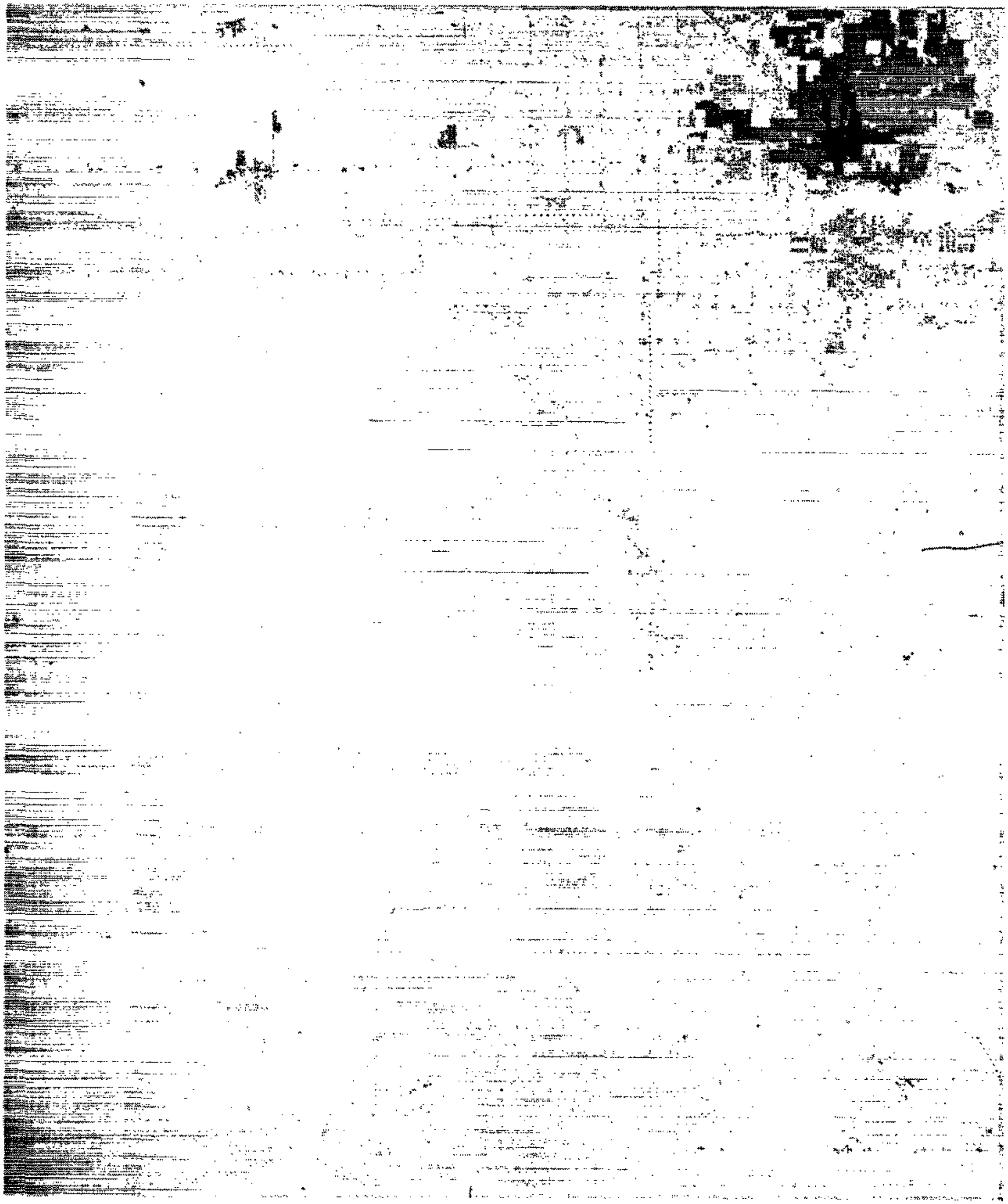

Figure 5   REFLECTANCE DATA DISPLAY

The cursor is visible when the Cursor On/Off function switch is set to On. Its position may be set with the joystick or by computer control. It is used in one of two ways. The first is as a reference marker for a geographical point. In this mode either the operator using the joystick or the computer using a latitude-longitude keyboard input can position the cursor to a particular reflectance data point. The cursor remains attached to this point even though the aperture of the display is changed or moved. Once the cursor is geographically off the display screen it does not reappear even though turned on unless its position is corrected by joystick or computer. The other use for the cursor is to read the contents of any data point. By positioning the cursor on the desired point, the operator may request an elevation or reflectance readout via keyboard and get the answer on the alphanumeric display. The operator may also request and get the latitude and longitude of a selected point.

Function switches are used for convenience in frequently exercised operations. Light pen and cursor function switches have already been discussed. The remaining switches are Reset, Display Elevation/Reflectance, Compare Old/New, and the Aperture Selection Matrix. The Reset switch initializes both computer and update console logic for system entry. Display Elevation/Reflectance selects the content of the data display and permits rapid alternate viewing of elevation and reflectance data for the same geographical area. Compare Old/New selects alternate sector memories which contain updated data and unaltered data respectively and permits rapid alternate viewing of old and new data. The aperture selection matrix provides means of selecting one of the three apertures for each data resolution group in Table I. The aperture may be moved in any direction in increments of 1/2 the smallest aperture for each data resolution group over the entire gaming area in regional memory by means of the inching arrow switches below the aperture selection matrix.

The operation of the system involves coordinated use of the console elements already described. Most operations are performed on the alphanumeric keyboard. To initialize the system, the operator presses Reset and enters the latitude and longitude of the area of interest along with the desired resolution on the keyboard. The resulting display is full aperture centered on the specified coordinates, and takes about one second to appear. Transformation of latitude and longitude to data base Cartesian coordinates is a computer subroutine used whenever such transformations are required, as with joystick/cursor operations. The reverse transformation, i.e., Cartesian to latitude and longitude, is also available as a subroutine.

Once initialized, the displayed area may be "flown" at any of three apertures over any of the four resolution groups of data over the entire regional memory using the aperture selection matrix and inching arrows. Map correlation is performed with the cursor and joystick either by locating displayed points on a map or by locating map points on the display. The common coordinate system between map and display is always latitude and longitude since the computer automatically transforms latitude and longitude coordinates and subsequently into display coordinates to translate cursor positions.

Having selected an area, the operator puts the system in update mode via keyboard. Update mode allows the light pen to be turned on. The aperture and resolution may be varied, and the display may be alternated between reflectance and elevation at any time. The light pen may be used to update data in any of three ways: discrete points, points in a line, or areas. The desired mode and the new elevation or reflectance are entered on the keyboard after which the light pen is used to indicate the points to be modified. Points and lines of points are modified as the light pen encounters them. Areas are circumscribed with the light pen and the enclosed area filled in automatically by the computer. The enclosing points must be adjacent to each other, i.e., sides or corners of the displayed square touching. The enclosing line of points is obtained by continuous movement of the pen through each point on the perimeter. The computer modifies each perimeter point as it is encountered but will not modify interval points until the perimeter is closed.

After completing update for the viewable area, the operator may check his work by joystick/cursor procedures for map/display correlation, or by alternately viewing old/new data or elevation/reflectance data using the function switches. The computer keeps both the original and modified data in sector memory during the procedure, so that in the four sector memories there is old and new elevation and old and new reflectance respectively.

To select a new area for update, the aperture is moved by inching to a new area and the update procedure repeated. Alternatively the operator can execute Reset and enter a new latitude and longitude coordinate pair for long geographical jumps. If the aperture re-enters an already updated area, the computer reconstructs the original and new data as separately viewable images in sector memory just as they were when updated the first time, thus preserving the old/new comparison capability.

At the conclusion of an update session, the computer has accumulated a number of modified blocks of data in district memory. These may be treated in one of three ways. If the number of blocks is small, they may be transferred directly to regional memory with address pointers to define modified memory contents. Large updates may be merged to magnetic tape along with old regional memory contents, so that a new regional memory loading tape is created. If the DRLMS is in demand for other tasks such as radar prediction or training, the updated blocks may be dumped directly to tape for later incorporation into regional memory.

Operator skills required for the update console system depend largely on whether the operator is required to interpret the radar significance of data to be entered, such as reflectance values. If the operator enters data from prepared worksheets and is not required to interpret maps or aerial photographs, the skill level required is probably commensurate with that of a senior technical typist or junior computer operator.

The time required for update also depends on the amount of interpretation required by the operator. The system will mechanically modify points as fast as the operator can find and point to them. With a problem involving a moderate amount of interpretation, such as positioning a new cluster of buildings, a known distance and direction from an existing landmark, the time required for a sample update would probably be as follows:

ACTION	TIME
Determine Coordinates, initialize system, select aperture	1 minute
Enter new data	2 minutes
Verify new data	2 minutes
Exit update mode to radar mode, verify new data on radar	10 minutes
	15 minutes

In a production situation, a skilled operator/supervisor would prepare worksheets from maps, aerial photos, and other source materials for incorporation into the digital data base. Since the interactive facility is primarily concerned with modifying or adding to existing data, these worksheets would be prepared by inspecting the data display and comparing it to a source graphic. Each worksheet would include at least one latitude and longitude fix and a gridded sketch of the modification to be performed. The operator would then follow the worksheet instructions without interpretation.

ACTION		TIME
Initialize system, select aperture		.5 minutes
Enter new data		1 minute
Verify new data		1 minute
	Total	2.5 minutes

If the average worksheet affected 10 data points, the production rate would then be 0.25 minutes/point.

Production rates are wholly dependent on the nature of the update problem. Movement of a shoreline or insertion of a large feature involves more data points then inserting small buildings or eliminating single point data anomalies. A better measure of production rate than points per unit time would be features or worksheets per unit time. At 2.5 minutes per feature production would be about 20 features per hour or 150 to 160 features per 8-hour shift. This does not account for worksheet preparation, the time for which would depend on the availability of the system and skilled personnel.

The fact that a computer is part of the interactive facility makes it possible to consider any number of new features to enhance production efficiency. For example, it may prove helpful to have the computer indicate geodetic north on the data display. Data grid north and geodetic north differ by the convergence of the Lambert conformal projection so that orienting a map to the display without this aid may be time-consuming. Another possibility is display of selected elevation points in profile rather than plan view to increase the number of viewable elevation steps.

The interactive facility described is conceptually applicable to any kind of DRLMS data base. The methods of data handling and modification described are usable in any interactive editing facility which deals with physical-world sensor simulation data, such as visual, IR, and LLLTV data. It would be necessary to change the data display to suit the data, but the CRT display allows a flexible choice of format. For example, one could choose stroke-writing for vector or line segment data and retain gray-shade raster or stroke-written number matrices for gridded data.

ABOUT THE AUTHOR

MR. ROGER C. DAHLBERG received a B.S. degree in Electrical Engineering from the Illinois Institute of Technology and a M.S. degree in Electrical Engineering from San Jose State.

At the present time Mr. Dahlberg is the digital systems engineer for the digital radar landmass simulator for the F-4F weapons system trainer. He is responsible for system design and coordination. This includes preparation of interface specifications, characterized and interpreted radar operation to the detail logic designers and programmers, defined hardware/software tasks, and conduct of design reviews. Mr. Dahlberg has complete responsibility for all aspects of radar data update including design of an interactive display console with a digitizing table, and development of cartographic mathematics to facilitate data modification.

Previous to his assignment to the F-4F weapons systems trainer program, Mr. Dahlberg was assigned to Singer's facility at Link-Miles Limited, England and had responsibility for the engineering support of manufacturing for Singer's GP-4B computers. These responsibilities included preparation of cost estimates for new contracts, providing technical advice to engineering and manufacturing related to the GP-4B computer, and liaison with vendors.

Prior to the Link-Miles Limited assignment, Mr. Dahlberg had designed and tested memory drum electronics for the GP-4 computer, used on various commercial and military aircraft simulators. He was responsible for design and prototype test of the feedback control for the memory drive used in the GP-4 to maintain drum memory speed at a rate in phase-lock with external timing signals. Mr. Dahlberg was responsible for the system design, breadboard, and final test of the drum memory logic and control portion of the Automated Microfilm Aperture Card Updating System (AMACUS). This included development of single bit alteration techniques on a large scale to permit rapid updating of memory contents, and the development of circuitry to permit video display of a stored digital picture.

Prior to joining Singer's Simulation Products Division, Mr. Dahlberg was engaged in electrical system design and analysis of Agena satellite vehicle programs. This work included design modification of solar array and power conversion equipment and associated control logic, as well as design of required telemetry readout circuitry.