A RADAR PREDICTION CONSOLE FOR PRE-MISSION PLANNING, TRAINING AND BRIEFING

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SUMMARY

The objective of a Radar Image Prediction System is to provide a pilot or navigator with a predicted image of his enroute and target area radar display so that he can become familiar with significant terrain and cultural features as depicted by his sensor system, plan his course, and practice various approaches for achieving his mission. The requirements of a Radar Image Prediction System are:

a. Develop a near-real-time realistic display simulation from a data base that defines terrain and cultural features.

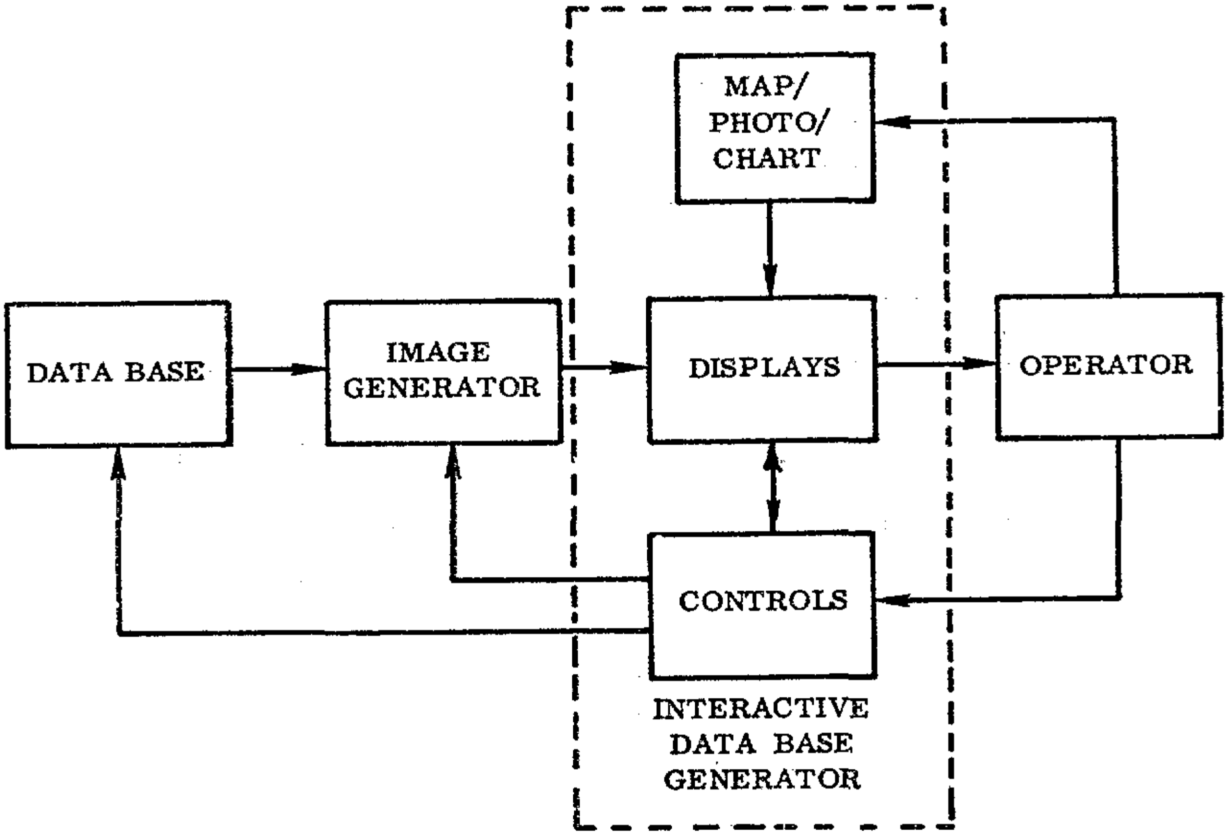
b. Provide a capability for quickly correlating the computed, or simulated, image with graphic (chart or photographic) data of the same area.

c. Provide an on-line capability to update or modify the computed image based on graphic source information.

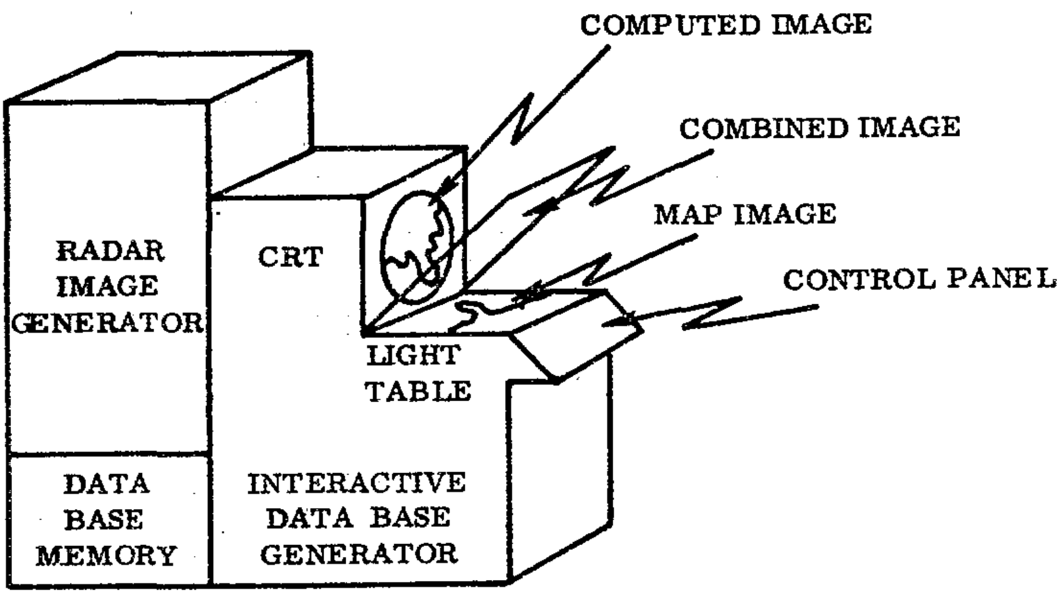
d. Provide an interactive display capability so that changes in the data base can be immediately viewed by the operator.

The Radar Image Prediction System that meets the above requirements is illustrated in the block diagram of Figure 1(a). The digital data base defines terrain elevation and cultural features by lines that are reflectivity boundaries and elevation features (ridge and valley lines) and by target points. The image processor reads the digital data base and converts the elevation and reflectivity data to a real-time radar image that is displayed on a PPI. The Interactive Data Base Generator provides the capability to correlate the computed image with a map or photo image and to modify the data base.

A sketch of the basic laboratory Radar Prediction System is shown in Figure 1(b). A 16K core memory that stores the data base and the high-speed image processor that generates the radar PPI display are mounted in one six-foot equipment rack. The Interactive Data Base Generator includes the displays, the operator controls, and the logic required for generating or changing the data base. The computed image



(a) BLOCK DIAGRAM



(b) CONFIGURATION

Figure 1. The Laboratory Radar Image Prediction System

is displayed on the vertical CRT. The image of the map or photograph is displayed on the horizontal light table. The two images are combined by a 45-degree beam splitter.

Figure 2 is a photograph of the Interactive Data Base Generator Console. All console controls are in operator language and are automated so that anyone familiar with radar prediction techniques can generate or change a data base using graphic source data. Several data bases have been developed on this console. U.S. Geological Survey maps were used as the graphic source data. The average encoding rate was 300 words per hour. This rate can be easily doubled by more human factor optimized controls and by experienced operators.

The resulting PPI display is a real-time, full three-dimensional, realistic simulation of the radar display. A pilot or navigator can "fly" the image, plan an optimum route to a target area, and become familiar with the terrain and cultural features of the target area as they will be displayed by the on-board radar system.

Figure 2. Interactive Data Base Generator

SYSTEM DESCRIPTION

The Data Base of Figure 1(a) defines terrain and cultural features by a series of digitally encoded lines that are reflectivity boundaries or terrain elevation features such as ridge lines, drainage lines or contour lines. In addition to the boundary/terrain lines, point targets are encoded to define small cultural features, such as buildings, ships or towers. Line targets are encoded to define elongated features, such as causeways, small streams or piers. Complex cultural features are defined by combinations of point and line targets.

The position (x, y and z) of a data base word is encoded to 16 bits accuracy. This provides a resolution of 10 feet in a 110 × 110 nautical mile data base. The words are encoded as a 16-bit start point and then an 8-bit Δx, Δy and Δz from the previous point. This format reduces the word length and still maintains a full 16-bit accuracy.

The line format data base provides the operator with the flexibility to define the target area with great detail and accuracy, while the approach to the target area can be defined by relatively few data words. In an operational situation, a relatively coarse data base may exist for a large area. The operator then can expand any part of this data base and use local maps or photographs to encode a target area with full detail and accuracy. This variable scene detail capability is inherent in the line format data base. Not only does this provide a required flexibility, but it also increases the efficiency of data storage and expedites data base development.

The Data Base Memory [Figure 1(b)] is a high-speed core memory that stores on line a 16,000-word data base. This data base is read by the Image Generator which converts the data base to a realistic simulation of a radar PPI display. The basic design of the Image Generator was described in the technical paper, "Digital Radar Land Mass Display Simulation," by R. A. Heartz, Proceedings of the Fifth Naval Training Device Center and Industry Conference, NAVTRADEVCEN 1H-206, pages 50 through 57.

The Image Generator develops a slant range PPI display with all radar special effects (i.e., beamwidth integration, shadow, incident angle, antenna pattern, far-shore enhancement, etc.) at a rate of a sweep per millisecond and with 1000 range elements per sweep. In data base generation, most special effects are bypassed so that a clearer image is achieved and the sweep is converted to a ground range presentation that can be directly correlated with a map or aerial photograph.

The Interactive Data Base Console provides the operator with the controls to: (1) correlate the computed image with a map image, (2) rapidly search the data base for a point of change or addition, and (3) directly generate a data base or change an existing data base using the map image. Figure 3 is a sketch of the operator control

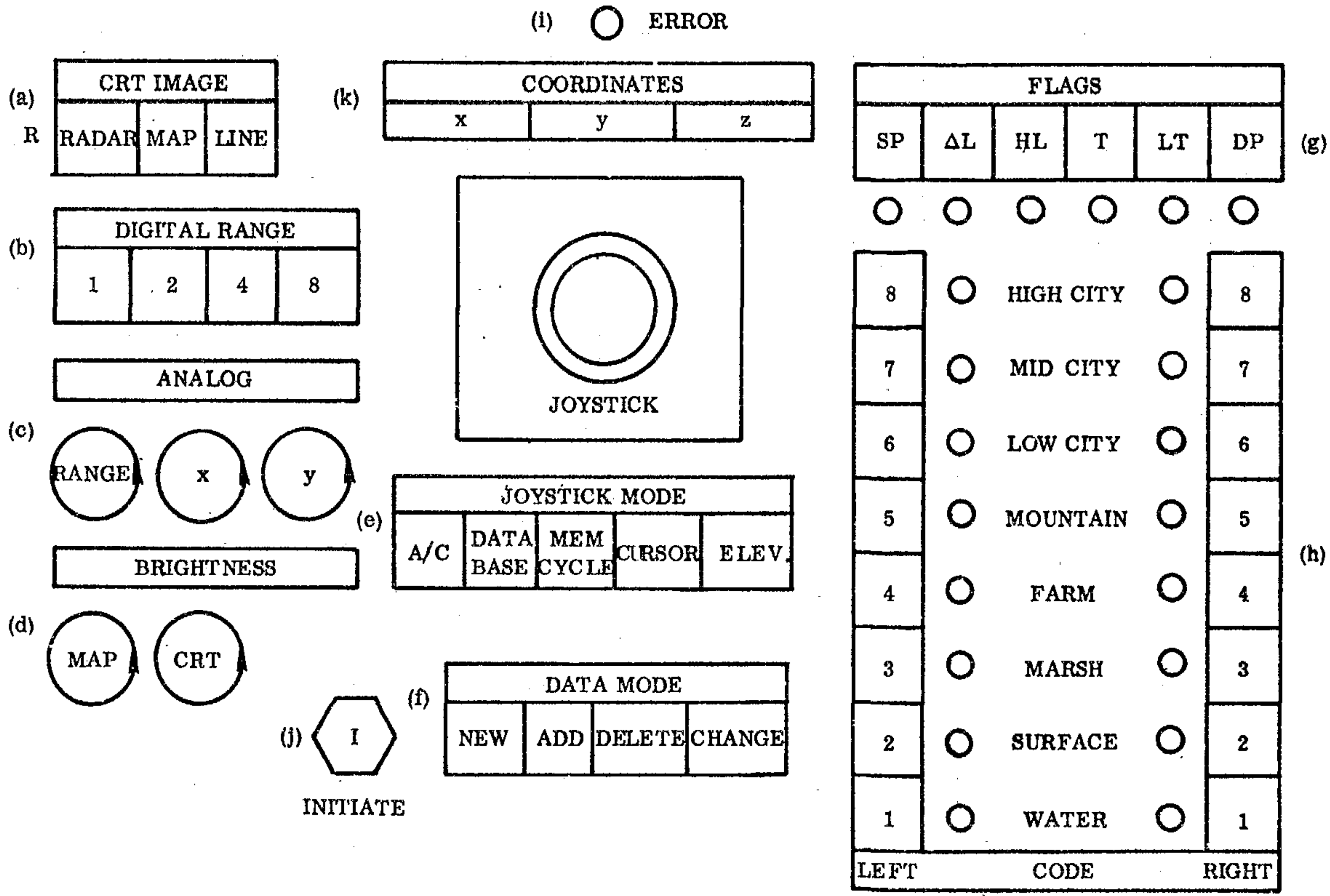


Figure 3. Control Panel Sketch

panel. The following is a brief description of the controls and displays, each identified by the letter in parentheses:

(a) CRT Image—These switches select the mode of operation of the Radar Image Generator. In the Radar mode, a realistic slant range PPI display with all radar effects is generated. In the Map mode, a ground range display is generated and radar special effects which tend to obscure the image are bypassed. In the Line mode, only the data base lines are shown.

(b) Digital Range—The computed image range can be selected in multiples of one, two, four, or eight.

(c) Analog—The computed image range can be adjusted between the digital ranges by a continuous analog control. Position of the image in x and y also can be adjusted by analog controls.

(d) Brightness—These are analog potentiometers that control the computed image video intensity and the brightness of the map image.

(e) Joystick Mode—The joystick control is shared by several operational modes: (1) Aircraft (A/C) Mode—forward or backward motion controls aircraft elevation, and right or left motion controls aircraft heading; (2) Data Base Mode—the joystick moves the data base in the x and y directions of the display; (3) Memory Cycle Mode—forward or backward motion counts the memory address up or down, and with each address count, the associated data base word is read out with x and y of the word displayed on the computed image by the cursor; (4) Cursor Mode—controls the x and y position of the cursor on the computed display; and (5) Elevation Mode—forward and backward motion of the joystick increases or decreases the elevation of a data base word.

(f) Data—There are four modes for implementing a data base change. In the New mode, the word is added to the last word in memory. In the Add mode, the word is inserted into the data base string following the current address word. In the Delete mode, the current address word is removed from the data base string. In the Change mode, the current address word is changed according to the control settings.

(g) Flags—The flags indicator denotes the type of data base word. The lights below the buttons define the flag of the current address word. The flags are start point (SP), delta line (ΔL), hidden line (HL), target (T), line target (LT), and dummy point (DP).

(h) Code—The code indicator defines the reflectivity code right and left of a delta line or the intensity and width of a target or line target. The lights beside the buttons define the current address word code. There are 16 code levels—eight are shown.

(i) Error—The error indicator is a light that will come on whenever the Δx and Δy of a word exceed eight bits. When this light is on, changes in the data base will not be implemented unless the Start Point flag is on.

(j) Initiate—Pushing this button implements the change or addition to the data base.

(k) Coordinates—This is a decimal display of the x, y, and z of the addressed word in the data base. When the joystick is in the Cursor or Elevation mode, the display reads out the x, y, or z of the changed or new word.

All controls are implemented directly with the Image Generator and Data Base Memory (Figure 1). The partial image is generated for 16 sweeps and then one sweep period is stolen to generate the cursor and implement the data base operational commands. Thus a data base change is implemented and displayed within one scan period.

DATA BASE GENERATION AND CHANGE

A data base usually develops in three phases: first, a reflectivity data base is generated; second, elevation features are added; and finally, point and line targets are added to define cultural features. These phases may merge, and there are no firm rules controlling the sequence. Data base generation somewhat naturally follows this pattern.

When generating a reflectivity data base, large strings of data can be generated where the only variables are x and y. For an example, a coastline has a constant elevation and right/left reflectivities. This string of data is rapidly encoded using the x-y cursor to trace the shore line and the initiate button to enter the data.

A large part of the elevation data base is encoded where the reflectivity right and left are the same and x, y, and z are the variables. Major ridge and valley lines are first encoded. Then, contour lines that define major features, such as a cliff, are encoded. The area is then cross-hatched with a few lines so that a complete elevation profile from any direction is defined.

Point and line targets, which are used to encode cultural features, are encoded and implemented as a delta elevation above terrain. Complex cultural features are encoded as clusters of line and point targets. Cardinal effects of cities are simulated by elevated line targets.

The operational steps for generating a new data base are:

a. Load 16K memory from storage with dummy points, and set range and elevation scales.

b. Mark map with start point and desired range scale.

c. Place map on light table, and set digital and analog range scale by viewing the combined images (i.e., high-intensity CRT range with map range).

d. Select start point mode, new data mode, and cursor mode for joystick.

e. Move cursor to start point, and press initiate button.

f. Select word flag (usually a delta line), reflectivity code, and move cursor to next point by viewing combined images.

g. If needed, select elevation mode for cursor and set point elevation.

h. Press initiate button, and then repeat steps (f) and (g) for next point.

Any word in a data base can be changed by locating the word, selecting the change in x, y, z, or code, and pressing the initiate button when in the data base change mode. Words can be inserted into the data base string (the Add mode) or deleted from the data base (the Delete mode).

The operational steps for changing an existing data base are:

a. Read data base from storage to 16K input memory.

b. Place map or photograph that defines the new data on light table.

c. Correlate computed image with map image by "flying" and scaling the computed image.

d. Place joystick in Memory Cycle mode, and cycle the cursor through the data base until point of change is located.

e. Select change and initiate.

f. Compare change with desired map or photograph, and initiate further changes if needed.

RESULTS

Figure 4 shows a computed radar image on the CRT and the map image from which the data base was developed. The beam splitter was removed for this picture. The area shown is Webster Field, Maryland. The ground radar range is 1.25 kilometers and the display resolution is 1.25 meters. This total data base covers an area of 8 × 10 nautical miles and contains 6000 data words. The displayed area (1.25-kilometer range) contains approximately 2000 words and represents the higher density and detail of a target area radar prediction.

The straight bright line on the right is a ten-foot-high chain link fence. The scattered bright returns in the lower part of the picture are trees. The data base was developed entirely on the laboratory Radar Image Prediction System and was encoded at a rate of better than 2000 words per day.

The data base was developed to simulate the display of a high resolution helicopter rotor blade radar system. The simulated display was compared over a wide range of positions (including on the ground) with photographs taken of the helicopter radar display. The correlation between simulated and radar displays was very good. The correlation between features, including shadows, was exact. However, the real display tended to have fewer grey shades and a more smeared and noisy image. The computed image shown in Figure 4 is a ground range presentation with most radar effects bypassed. Thus this image is much more sharp and stylized than the true radar image.

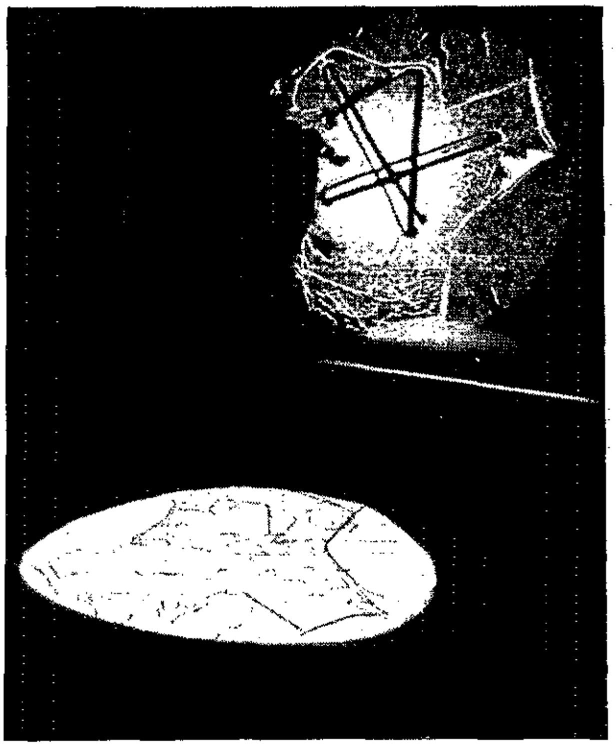


Figure 4. Map and Computed Images

CONCLUSIONS

Several problems posed at the outset of this development were:

a. Can the normal PPI image, when combined with a map image, provide a sufficiently bright and clear image for data base generation?

b. Can the image generation system be effectively time-shared with the data generation system?

c. Can the data base generation and change logic and controls be designed for easy direct user operation?

The results of the project provided a definite affirmative answer to these questions. While for direct data base viewing and correlation a bright continuous TV image would have advantages, the PPI image proved to be adequate, to have much better flexibility, and to be much more cost effective. Direct special logic to interface the operator controls and to implement data base changes proved to be operationally effective and with a much lower cost than using the usual general-purpose computer type interface.

Unique features that this Radar Prediction System provides are:

a. A fast correlation of images that is accomplished by digitally "flying" and scaling the computed image—Optical problems in aligning and scaling the map are minimized.

b. Combined images that are easy to identify visually because the direct projected graphic image has unique visual characteristics relative to the computed CRT image—When images are combined on a single CRT, it is difficult to distinguish between images unless different colors are used.

c. A wide window-display viewing area that allows the operator positional freedom—His head is not constrained to a binocular viewing system.

d. Time-shared processing for data base changes and cursor location—This reduces hardware and assures integrated accuracy and resolution.

e. A cursor that is independent of the sweep—This provides a bright, easily recognized cursor point.

f. A data base cycle mode that allows an operator to quickly locate and to read out any word in the data base—Computer tabulations (printouts) are not required—The data base itself provides all records.

g. Data base inputs and readouts that are automated so that controls and displays are in direct operator language—The operator does not have to learn a "computer language" to operate the system.

h. Data base changes or additions that are implemented and displayed within one scan period.

ABOUT THE AUTHOR

MR. R. A. HEARTZ is currently project engineer of the IR&D digital radar display simulation development programs at General Electric Company. He initiated the digital radar simulation project in 1968. He was responsible for the development of the first laboratory model of a real-time digital radar display simulator. Demonstrations of this system in early 1970 proved the feasibility of the digital approach. In 1972 he developed the Radar Image Prediction Device.

From 1960 to 1968, Mr. Heartz was manager of a unit that was responsible for the simulation analysis of the Apollo system. Prior to the Apollo program, he was a specialist in the advance development and analysis of radio and inertial guidance systems. He was one of the originators of the radio-inertial guidance system that was used in all of the Mercury space flights. Before joining the General Electric Company in 1955, he was a research engineer and project engineer responsible for the advance development of inertial guidance equipments with the Aero Research Department of Honeywell, Inc.

Mr. Heartz received a B.S.E.E. degree from the University of New Hampshire in 1949. He received a M.S.E.E. degree from South Dakota State College in 1950. He has authored many technical papers and holds three patents. He is also the inventor of two patent applications relating to radar display simulation.