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Development and Use of Interactive Displays in Real-Time Ground Support Research Facilities

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SUMMARY

The National Aeronautics and Space Administration (NASA) Western Aeronautical Test Range (WATR) is one of the world's most advanced aeronautical research flight test support facilities. A variety of advanced and often unique real-time interactive displays has been developed for use in the mission control centers (MCC) to support research flight and ground testing. These displays consist of applications operating on systems described as real-time interactive graphics super workstations and real-time interactive PC/AT compatible workstations. This paper reviews these two types of workstations and the specific applications operating on each display system. The applications provide examples that demonstrate overall system capability applicable for use in other ground-based real-time research/test facilities.

NOMENCLATURE

CAP	color alphanumeric panel
CGA	color graphics adapter
CPU	central processing unit
DMA	Defense Mapping Agency
DSP	digital signal processing
EGA	enhanced graphics adapter
ETA	estimated time of arrival
MAGIC	master graphics interactive console
MB	megabyte
MCC	mission control center
MDA	monochrome display adapter
NASA	National Aeronautics and Space Administration
PC	personal computer
RIM	real-time interactive map
STM	short-term memory
TACAN	tactical air navigation station
TRAPS	telemetry/radar acquisition and processing system
USGS	United States Geological Survey
WATR	Western Aeronautical Test Range

INTRODUCTION

A wide variety of research display needs must be met to support research flight and ground testing. Real-time data display is a key element in all research test applications. The goal of WATR display system developers at NASA/Ames Research Center, Western Aeronautical Test Range is to develop a generic display system capability that supports an entire set of research test requirements.

Recently developed generic interactive real-time processing and display systems can display not only raw data but also processed information. The display systems developed by the WATR for support of research flight and ground test access data from a real-time processing engine, process that data locally in the display system and generate the required display. The display of processed information is integral for support of cost effective, safe, and productive research flight and ground test. In this paper the real-time display systems are defined as real-time interactive graphics super workstations and real-time interactive PC/AT compatible workstations. Specific applications developed by the WATR for each display system provide examples of overall system capability and demonstrate how each can be applied in other ground-based, real-time research/test facilities.

DISPLAY SYSTEMS

Real-time interactive display systems discussed in this paper can be divided into two categories: real-time interactive graphics super workstations and PC/AT compatible workstations. The main distinctions between these types of workstations are capability and cost. Real-time interactive graphics super workstations can support high-speed data processing for a large quantity of data for generation and manipulation of high-resolution graphics displays. On the other hand, PC/AT compatible workstations can process a smaller quantity of data at high speeds compared with real-time interactive graphics super workstations and contains some graphics capability. Cost could be a significant factor in display system development. Real-time interactive graphics super workstations cost ten times the price of PC/AT compatible workstations. Both types of systems are required to cover the broad spectrum of applications.

REAL-TIME INTERACTIVE GRAPHICS SUPER WORKSTATION

Real-time interactive graphics super workstation can process large quantities of data while creating complex display formats at a quick response rate. This workstation (figure 1) is a 32-bit UNIX-based workstation that consists of commercially available hardware with custom-tailored application software packages. Rack-mounted workstations installed in the mission control center allow the flight researcher to determine the display format, color, and quantity of information displayed.

The complete workstation includes a high-resolution, 1024-by-768 pixel screen capable of displaying 4096 colors simultaneously, double-buffered from a palette of 6.7 million colors. The chassis accommodates up to 16 megabytes (MB) of memory in the central processing unit (CPU) using 32 bit-planes of display and a 170-MB hard disk. Each workstation is equipped with a color monitor, keyboard, color hardcopy unit, and mouse.

The basic workstation possesses the computational power to support many real-time display requirements. Custom tailoring of the application software on a generic display system provides a cost-effective and efficient approach. To demonstrate the capability provided by this workstation, two applications, real-time interactive map (RIM) and master graphics interactive console (MAGIC), are discussed. These two applications have dissimilar requirements and demonstrate the flexibility provided by this generic display system.

Real-Time Interactive Map (RIM)

Two-dimensional electromechanical pen and ink plotboards were used for many years to display the radar-derived location of research aircraft flying in the Edwards Air Force Base air space. These plotboards became increasingly difficult to maintain and did not provide the flexibility to support future complex research flight test mission requirements.

The application software package that is the nucleus of the computer-generated mapping system is known as the real-time interactive map (RIM).[1] The RIM application is an interactive program written in "C" language that consists of approximately 7000 lines of code and is controlled by mouse, keyboard input or both. The database for development of the map was created using established United States Geological Survey (USGS) and Defense Mapping Agency (DMA) databases. Real-time data for generation of the display is derived from precision tracking space positioning and downlink telemetry data.

Once the database is generated, rendering information is added to instruct RIM how to display the data, either as lines, points, or filled surfaces. Information such as coloring, clipping, and hidden line removal is also added. The information is then grouped together by feature to allow the RIM operator to select the level of display detail required for the particular test activity and the desired view. By default RIM displays a two-dimensional map (figure 2) with the vehicle trail represented as a white line.

To ensure that aircraft stay within the boundaries of their assigned restricted areas, RIM has the capability to monitor and provide a warning indication if the vehicle descends below the predefined restricted altitudes. In addition users may also instruct RIM to compute and display the distance from the aircraft to the nearest edge of the restricted area. By reducing the amount of data that mission controllers have to manually process, this system allows them to better focus their efforts on monitoring overall flight conditions to assure research/test objectives are accomplished and improve the overall safety of research flight testing.

By a simple keyboard entry RIM can compute and update vehicle location in relation to any point on the map by providing a digital display of heading, deviation, distance in nautical miles, and estimated time of arrival (ETA) to that point (figure 3). The RIM application also provides a digital readout (figure 4) of the vehicle's bearing and distance from both NASA and the Edwards tactical air navigation station (TACAN). This aids mission controllers when vectoring a chase aircraft to the test vehicle. Another feature allows mission controllers to overlay a compass rose (figure 5) on the image of the research vehicle. This compass rose, marked in degrees, assists controllers in issuing course corrections during flight. Still another feature is the ability to enter and display a predetermined flightpath. This helps controllers detect deviations from the proposed flight plan and is particularly useful in trajectory guidance programs.

A generic cockpit instrument display (figure 6) can be enabled to provide basic aircraft attitude, heading, vertical speed, and altitude. This provides the controller with a realistic graphic display of actual cockpit instruments. While currently generic, these instrument displays can be customized for realistic simulations of specific aircraft cockpits.

By menu selection (figure 7) the user can enable or disable map features. The operator can select levels of detail to be displayed on the map. By disabling certain map features, the map becomes less cluttered and allows the operator to see only those points of immediate interest. At any time the operator can "zoom" in or out on the map as well as translate the map in any direction. These capabilities are also provided automatically by RIM, again reducing the amount of operator intervention required.

In addition, RIM makes use of the three-dimensional capabilities of the graphics workstation. By applying certain transformations to the map, a view can be simulated from either the cockpit (figure 8), an imaginary chase plane (figure 9), or the ground (figure 10). The views provide alternate perspectives to help visualize the aircraft's attitude and flightpath.

MAster Graphics Interactive Console (MAGIC)

Master graphics interactive console (MAGIC) is a resident real-time display tool available for support of research flight or ground tests in the MCC. The MAGIC software package provides a general-purpose real-time graphics display system for real-time and post real-time data analysis, as discussed in reference 2. The MAGIC application is also an interactive program written in "C" language that consists of approximately 7000 lines of code that allows researchers to create their own displays during preflight, real-time, and postflight checks, based on individual requirements.

The MAGIC application provides four major types of information displays used in ground testing:

1. Time histories from a real-time database
2. X & Y plotting from real-time data
3. Digital display of discrete or logical parameters from a frame of real-time data and messages and data written to the graphics workstation textport
4. The capability of displaying predicted data in real-time applications

The powerful MAGIC application allows the user 10 pages of graphics display capability. Each page can be individually defined and created at the discretion of the user. Requirements for development of this application created the following envelope of capability for each page:

1. maximum of 16 graphs
2. maximum of 64 plots
3. maximum of 64 parameters
4. maximum of 80 polygons (predicted data envelopes)

Each graph (figure 11) displayed on a page is independent of all graphs on the page. A graph is built to the specifications for that particular illustration. This allows the user to specify the limits of the X axis and Y axis. Each axis requires a minimum value, a maximum value, and the number of divisions required between the minimum and the maximum limit.

The graph in figure 12 is a time history containing an x parameter and a y parameter and is considered as one plot. The x-parameter data value and the y-parameter data value will be plotted according to the limits assigned to the graph. A graph must contain at least one plot and may contain a maximum of 16 plots per page on that one graph. However, it is inconceivable that this many plots would actually benefit any display.

Digital parameters displayed in engineering units shown on the left side of figure 11 and are available for a user requiring information displayed in a numerical state. The digital parameters may be placed anywhere on the screen and their value processed as real, integer, or logical. If the digital parameter is a real value, then the amount of precision can be determined and assigned to that digital parameter.

A user may wish to predict a limit within a graph that is to be assigned to a plot through a polygon displayed on that graph (figure 13). The size of the polygon and the number of points within the polygon are at the discretion of the user. The constraints for polygons are five polygons to any one graph and 2 to 50 points to build the polygon.

As demonstrated, the real-time interactive graphics super-workstation has immense capability to support diverse graphics applications related to flight and ground testing.

REAL-TIME INTERACTIVE PC/AT COMPATIBLE WORKSTATION

Using a personal computer for graphics and data display is not a unique application. However, the use of this type of system in a real-time environment without a large back room processor for display generation is unique. The class of system referred to as a real-time interactive PC/AT compatible workstation (figure 14) is a 32/16-bit MS-DOS-based workstation that consists of commercially available PC/AT compatible hardware. This system is capable of creating display formats using commercially available or custom application software.[3] Rack-mounted workstations installed in the mission control center environment will interactively allow the flight researcher to determine the display format, color, and quantity of information displayed.

The workstations to be used in the MCC are based on a 7 in.-high rack-mountable chassis. This chassis contains a ten-slot "passive" AT bus plane, fans, a 220-W power supply, and the mounting hardware necessary for disk and tape drives. The basic system will contain a 386 CPU card with 4 MBytes of memory, a disk controller card for up to two floppy drives, and two hard drives. It also contains a video adapter card capable of displaying the monochrome display adapter (MDA), color graphics adapter (CGA), or enhanced graphics adapter (EGA) video standards. It is also planned that several PC/ATs will contain Ethernet cards, IEEE 488 cards, and an array processor capable of 10 MegaFlops.

The basic workstation possesses the computational power to support many real-time display requirements. Commercially available or custom-tailored application software running on a generic display system provides the cost-effective and efficient approach to support displays that do not require the processing and display capability of the graphics workstation. To demonstrate the capability provided by this workstation, two applications are discussed: The color alphanumeric panel (CAP) is a status/alert display application software package. The DSPlay is a digital signal processing (DSP) software package.

Color Alphanumeric Panel (CAP) Displays

The two primary status/alert displays currently used in the WATR MCCs each have two pages. These are the two alphanumeric displays (ANCRT #1 and ANCRT #2) and the two color panel displays (CP #1 and CP #2). The ANCRT screens display six-digit numeric data directly following or directly below a parameter identifier. This data can be presented in formats of quarter screen, half screen, or full screen using either fixed position numerics or scrolling numerics. Figure 15 is an example of a typical ANCRT screen. The two color panel screens utilize eight-color character graphics in an 80-by-40 character matrix to generate their displays. Each matrix position is defined by an alphanumeric character or shape, foreground and background color, and whether or not it is to blink. This capability allows the user to build a variety of screens. Figure 16 is an example of a typical color panel display. The ANCRT and color panel displays can be used to implement bar graphs, scrolling time histories, and X-Y plots. These displays can also mimic aircraft cockpit displays.

The real-time interactive PC/AT compatible workstation can support an integrated application called CAP. This application software package will replace the functions provided by ANCRT #1 and #2 and color panel #1 and #2 displays. This provides additional capability and flexibility by creating a custom application on a generic display system. The CAP display will be running in the text color graphics mode supported by both the MDA and EGA graphics video standards for PC/ATs. Both the ANCRT and color panel programs run in a similar mode. The CAP display will accept setup information downloaded from the telemetry/radar acquisition and processing system (TRAPS), the core real-time processing system. The CAP display must then build its displays based on an 80-column, 40-row character matrix using either alphanumeric or graphics characters with color attributes. Figure 17 shows such a matrix with examples of alphanumeric data and color panel-type-graphics in quarter-page formats.

DSPlay Application Software

With the addition of the commercially available software package DSPlay, the PC/AT compatible workstations can be used for real-time frequency analysis in the MCC. The DSPlay software implements DSP algorithms in "FlowGrams" and "SubGrams" through flow-chart-type programming (figure 18). Flowgrams and Subgrams correspond respectively to programs and subroutines in more conventional programming terms. The Flowgram is a block diagram that details the flow of signals through a DSP process. To assemble a Flowgram on the screen, the engineer chooses from a selection of functions and places these functions, through editing commands, into the individual blocks. While editing, the user determines the parameters of each function block and draws the required interconnecting lines. By placing the cursor over any individual block while in the Block mode and pressing ⟨ENTER⟩, the engineer can view, print, and edit the parameters for that block. Press ⟨ESC⟩ when viewing and editing are complete. This also works for viewing, printing, and editing the parameters unique to the entire Flowgram while in the Flowgram mode. Each block represents a signal processing function, and the lines indicate the flow of the signal. A Flowgram can have up to 30 blocks in it; however, an individual block can represent a SubGram that in turn can have up to 30 function blocks. DSPlay takes data in a simple ASCII file format of floating point numbers. Figure 19 is an example of a typical display generated by DSPlay.

These applications demonstrate the power and flexibility provided by the real-time interactive PC/AT compatible workstation. With the basic generic processing capability provided by the workstation utilizing custom or commercially available application software, it is apparent that many other display applications can be accommodated on this system. The real-time interactive PC/AT compatible workstation allows for cost effective and efficient development of custom display formats to support unique flight and ground testing display requirements.

CONCLUDING REMARKS

The development and use of advanced interactive real-time display systems within the WATR has contributed to the success of the NASA aeronautics program. This technologically advanced approach to interactive real-time display system development and use will continue to advance methods for safe, cost effective, and productive research flight and ground test support. This paper discussed two categories of systems, real-time interactive graphics super-workstations and real-time interactive PC/AT compatible workstations and some specific applications that operate on each type of system. Despite the apparent highly specialized nature of the WATR developments, this capability is suitable for use in a much wider variety of situations. The WATR development team continues to work toward providing a capability that presents answers in real-time required by the test team without requiring custom development for individual research tests.

Ames Research Center
Dryden Flight Research Facility
National Aeronautics and Space Administration
Edwards, California, September 30, 1988

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Malone, Jacqueline C. and Archie L. Moore, *Western Aeronautical Test Range Real-Time Graphics Software Package MAGIC*, NASA TM-100425, 1988.

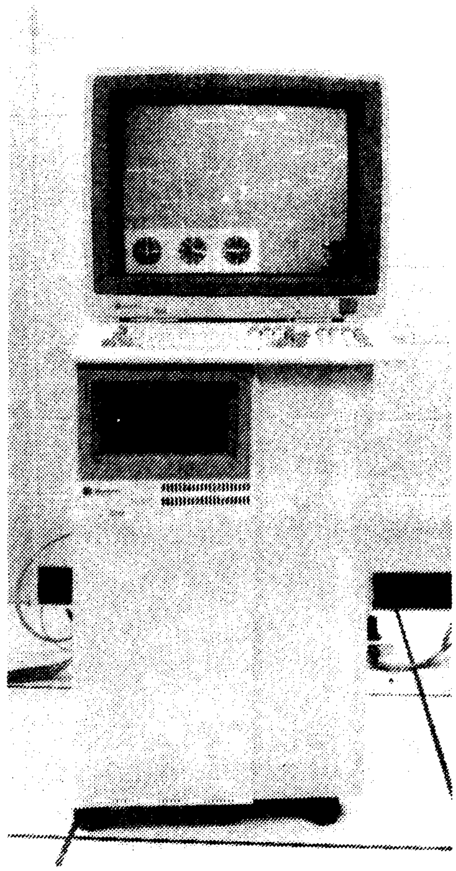

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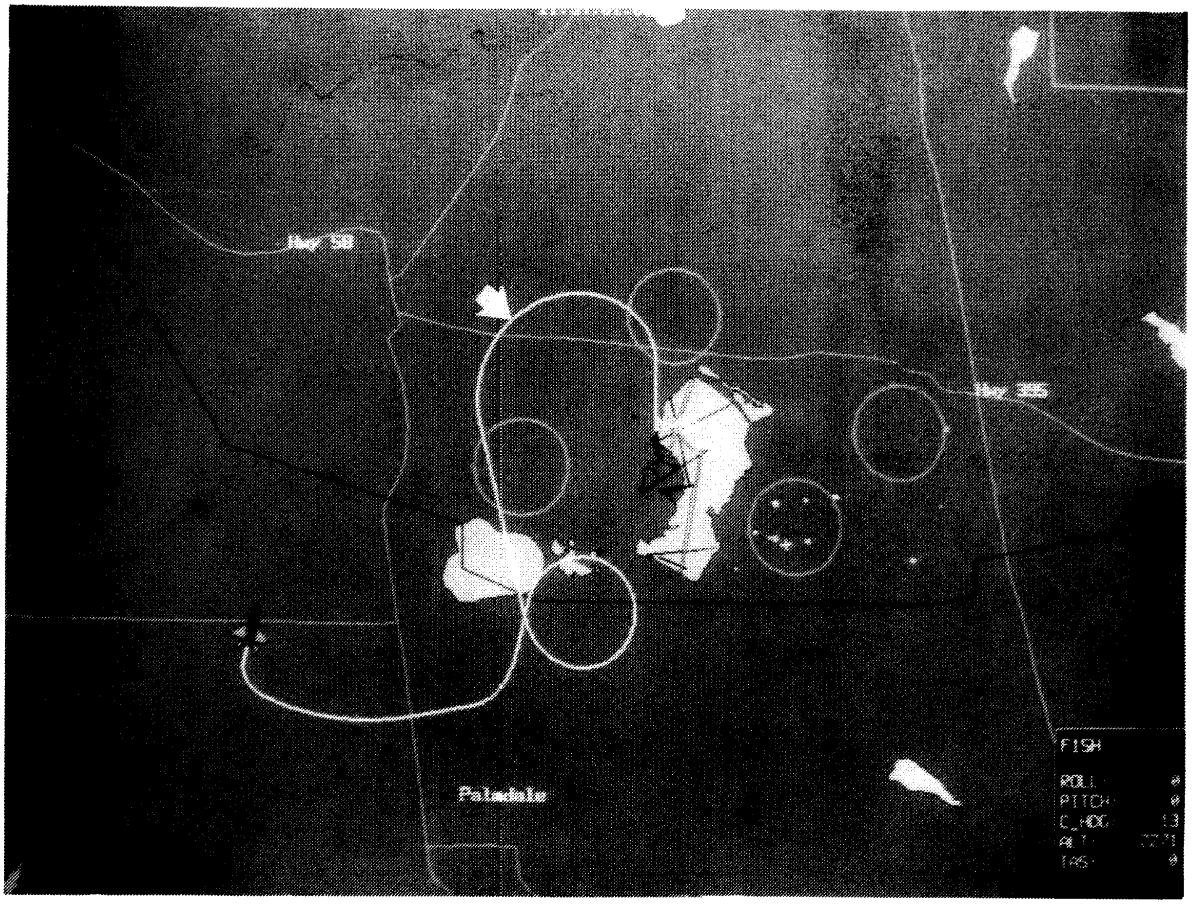
Figure 1. Real-time interactive graphics super workstation.



EC88-0002-003

Figure 2. RIM display with vehicle trail.

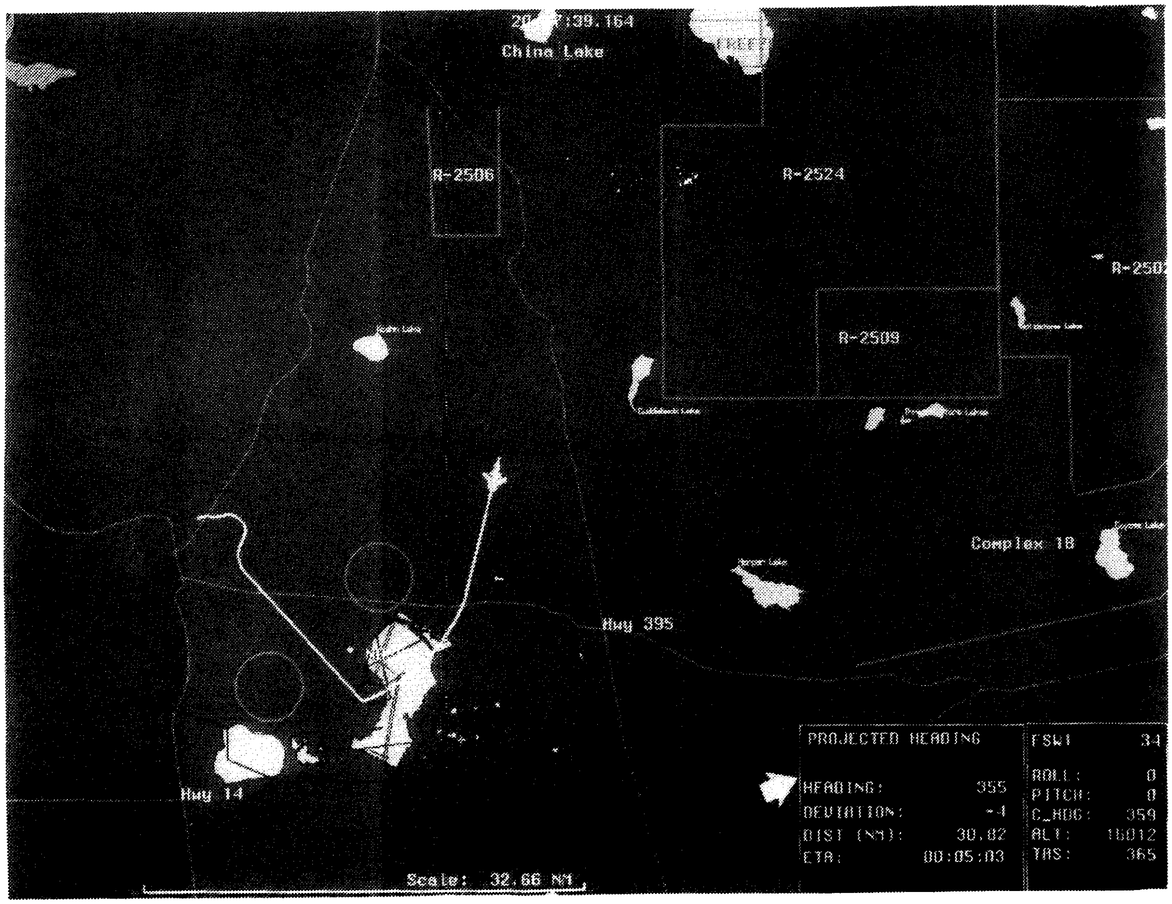
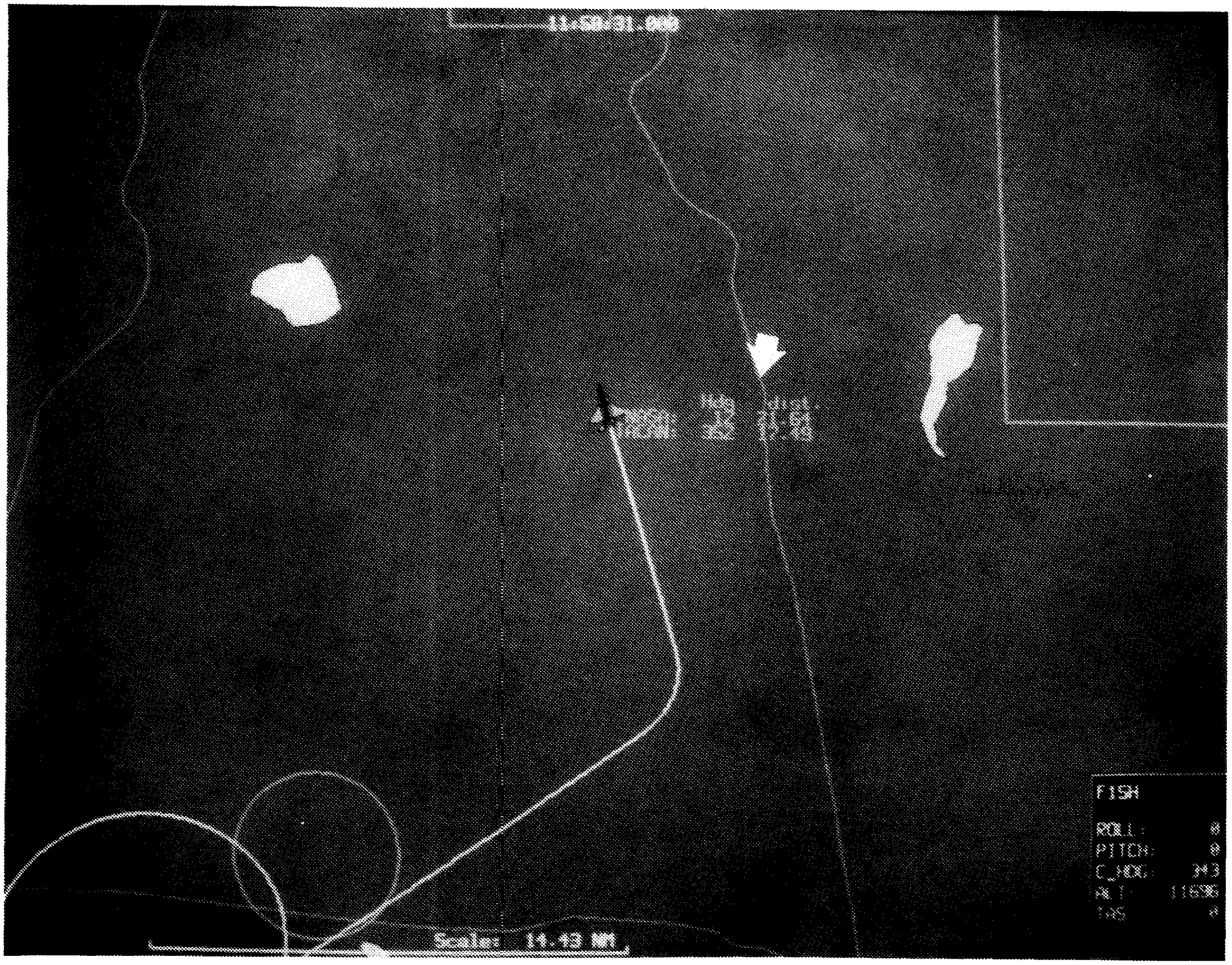


Figure 3. RIM display with projected heading digital display.



EC88-0002-028

Figure 4. RIM display with bearing and distance readout.

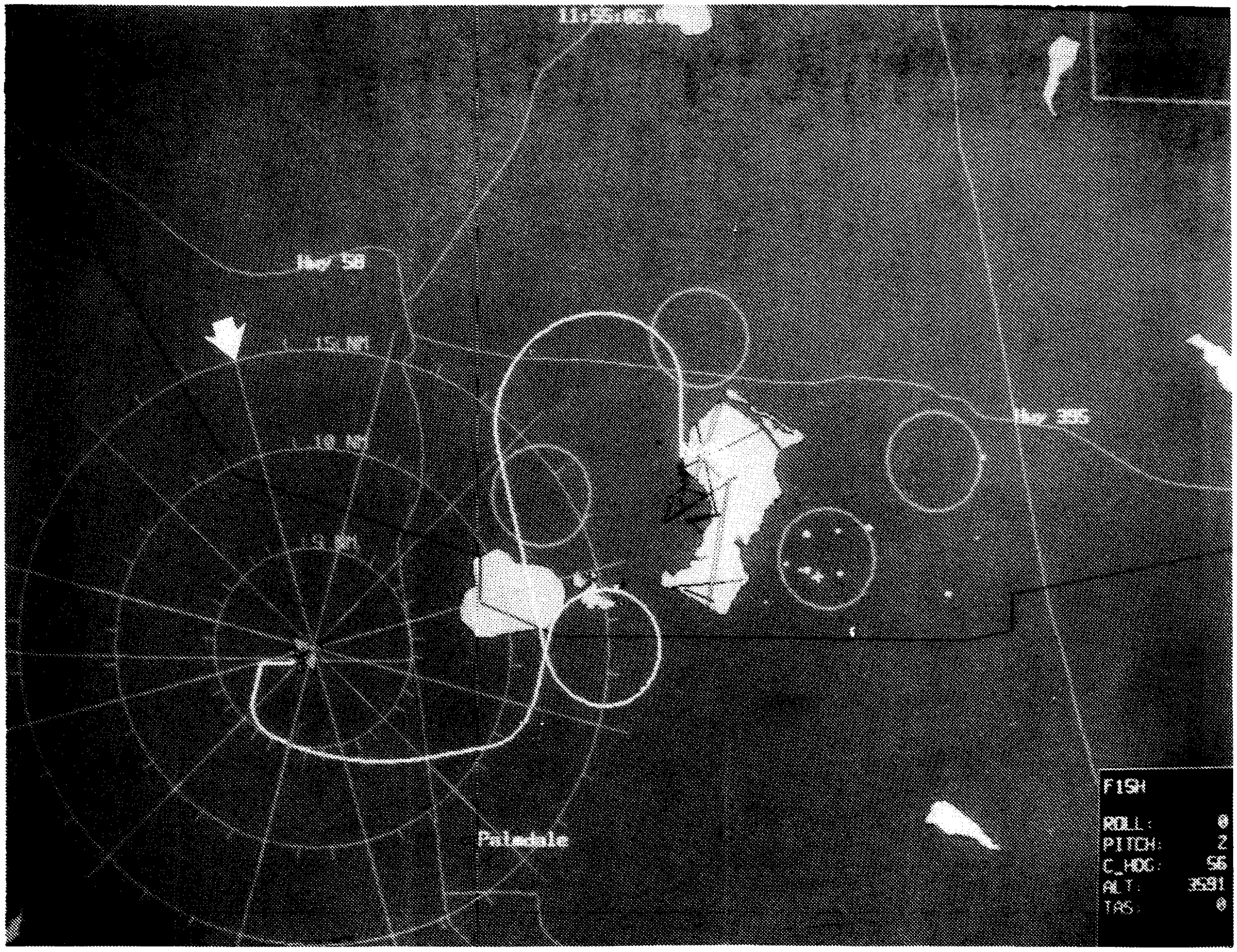


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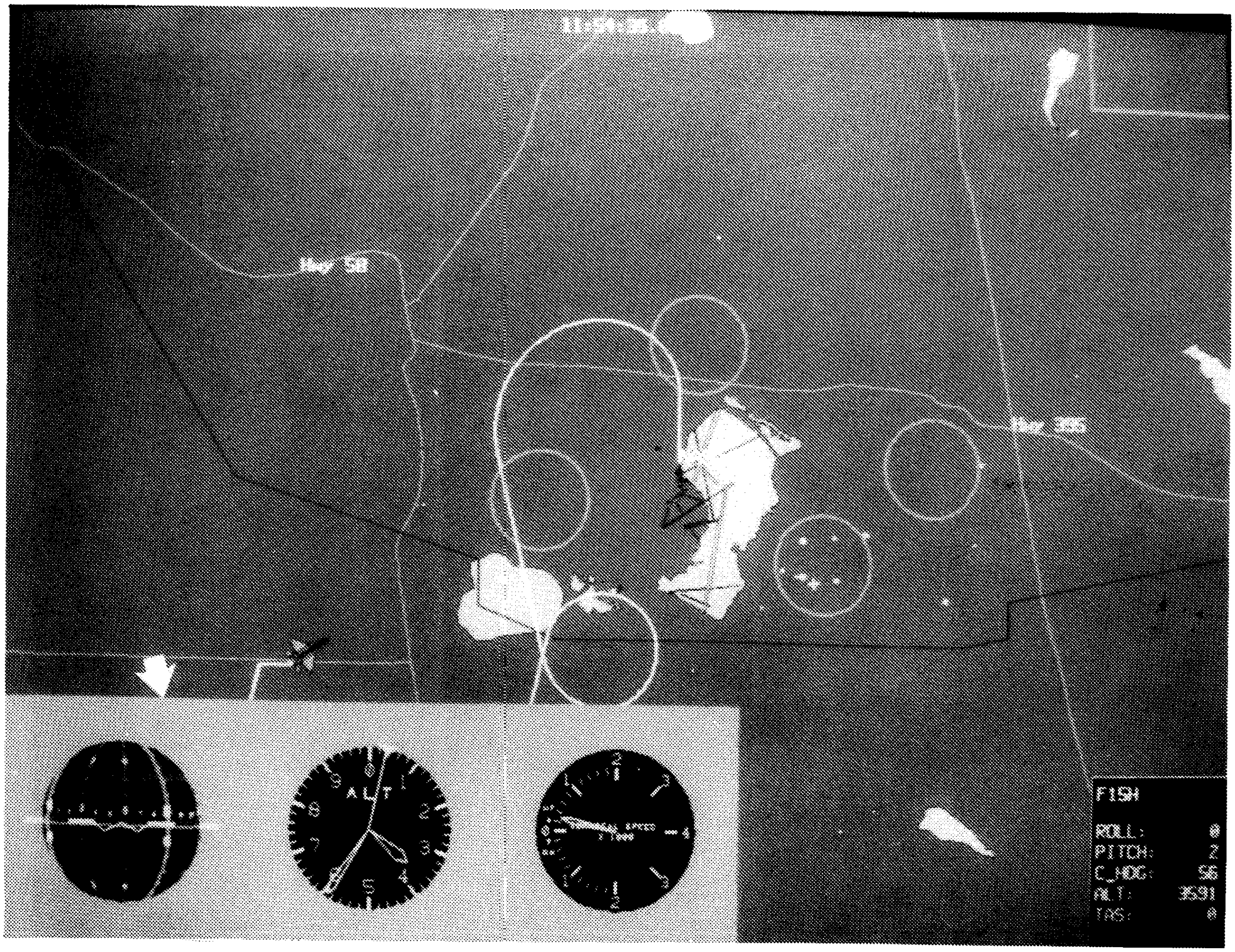
Figure 5. RIM display with compass rose overlay.



EC88-0002-004

Figure 6. RIM display with cockpit instrument display.

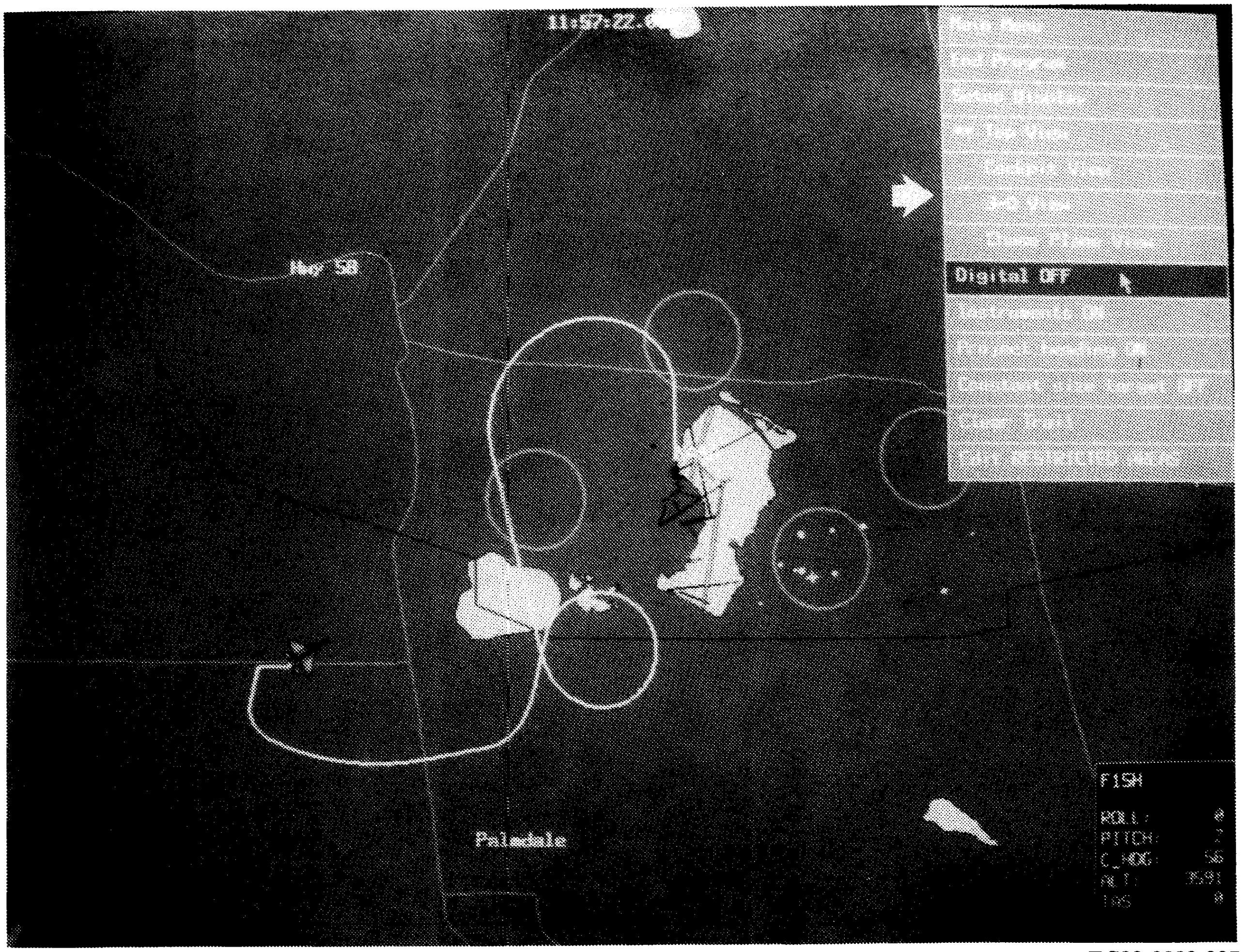


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Figure 7. RIM menu selection.

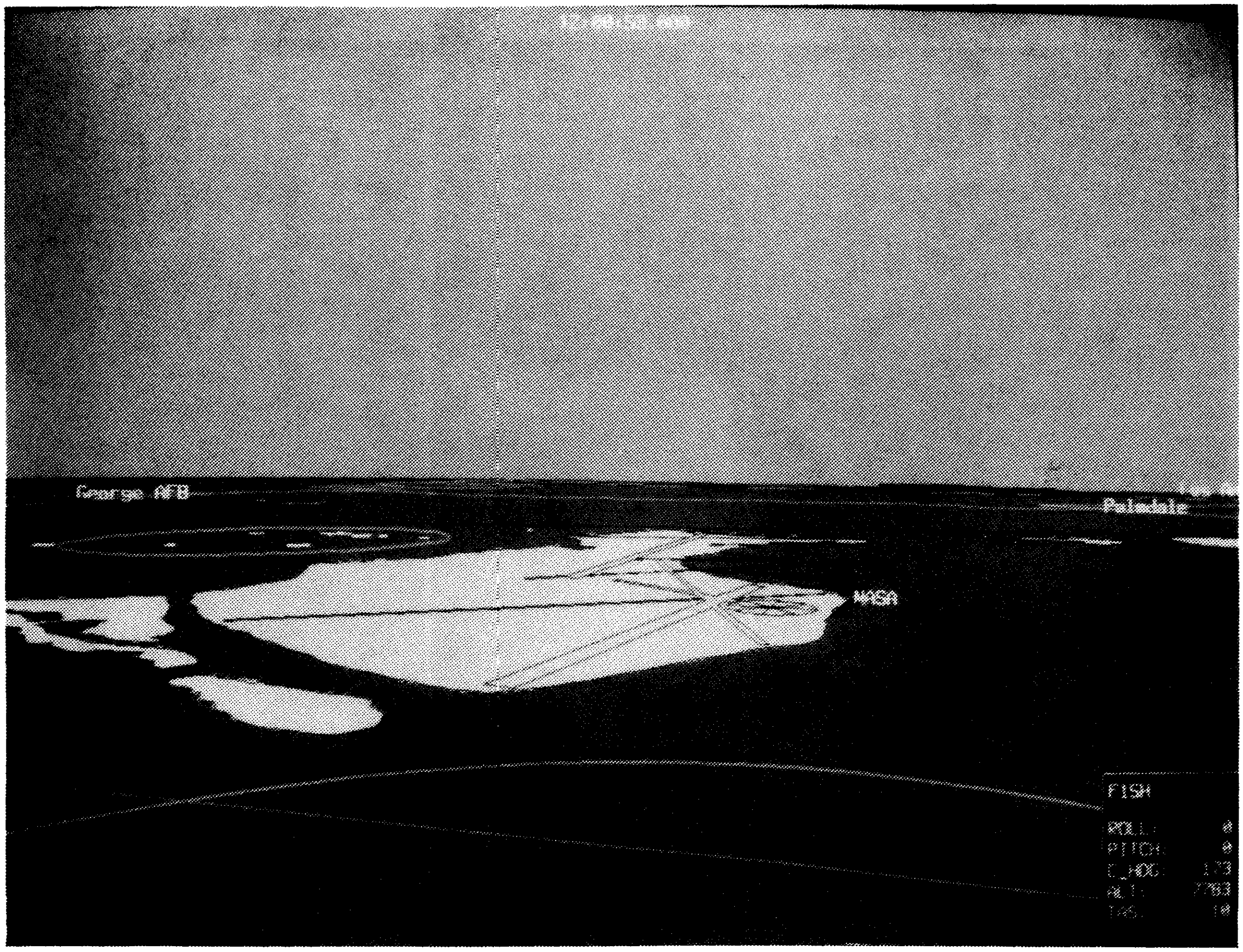

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Figure 8. RIM display, 3-D cockpit view.

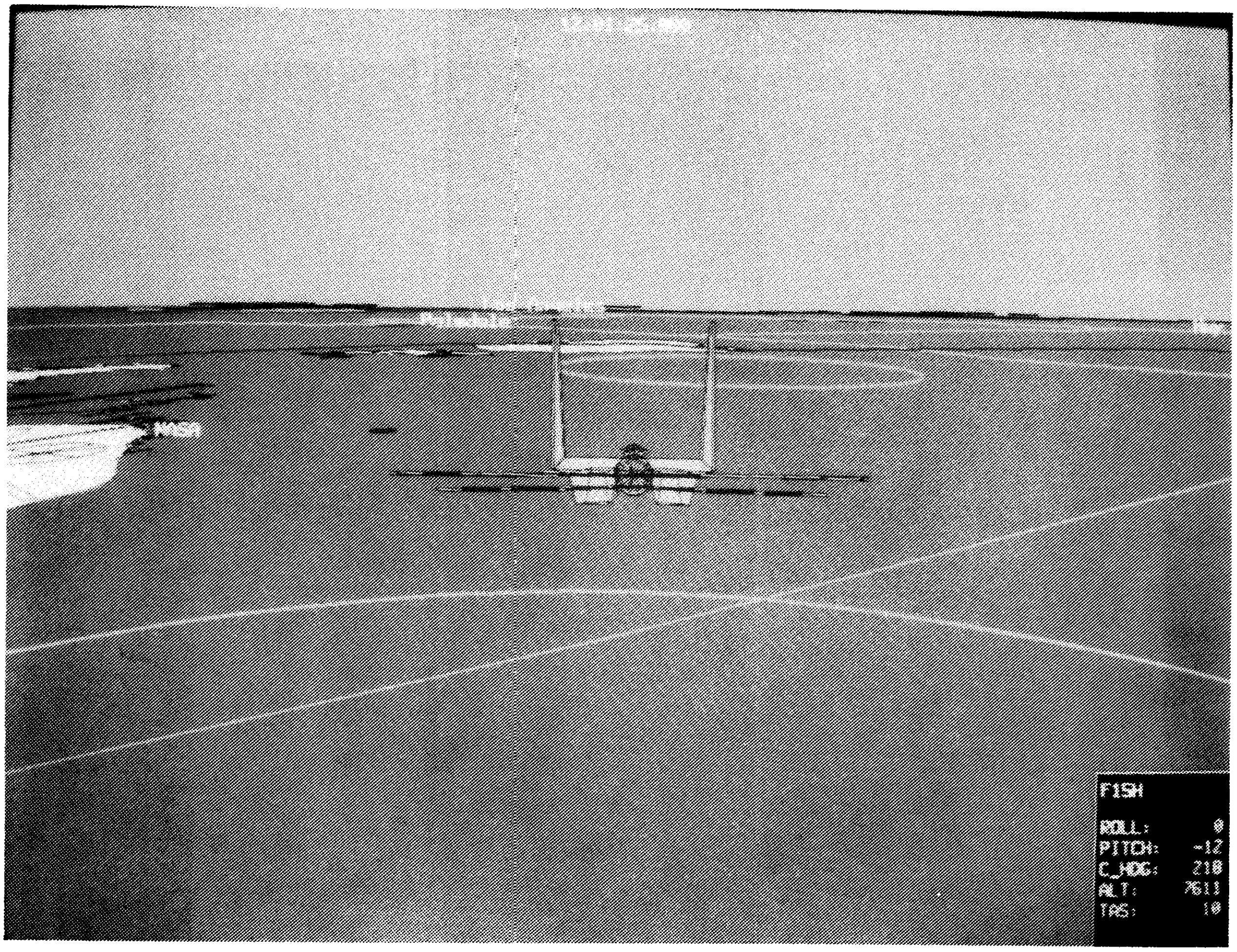

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Figure 9. RIM display, chase plane view.

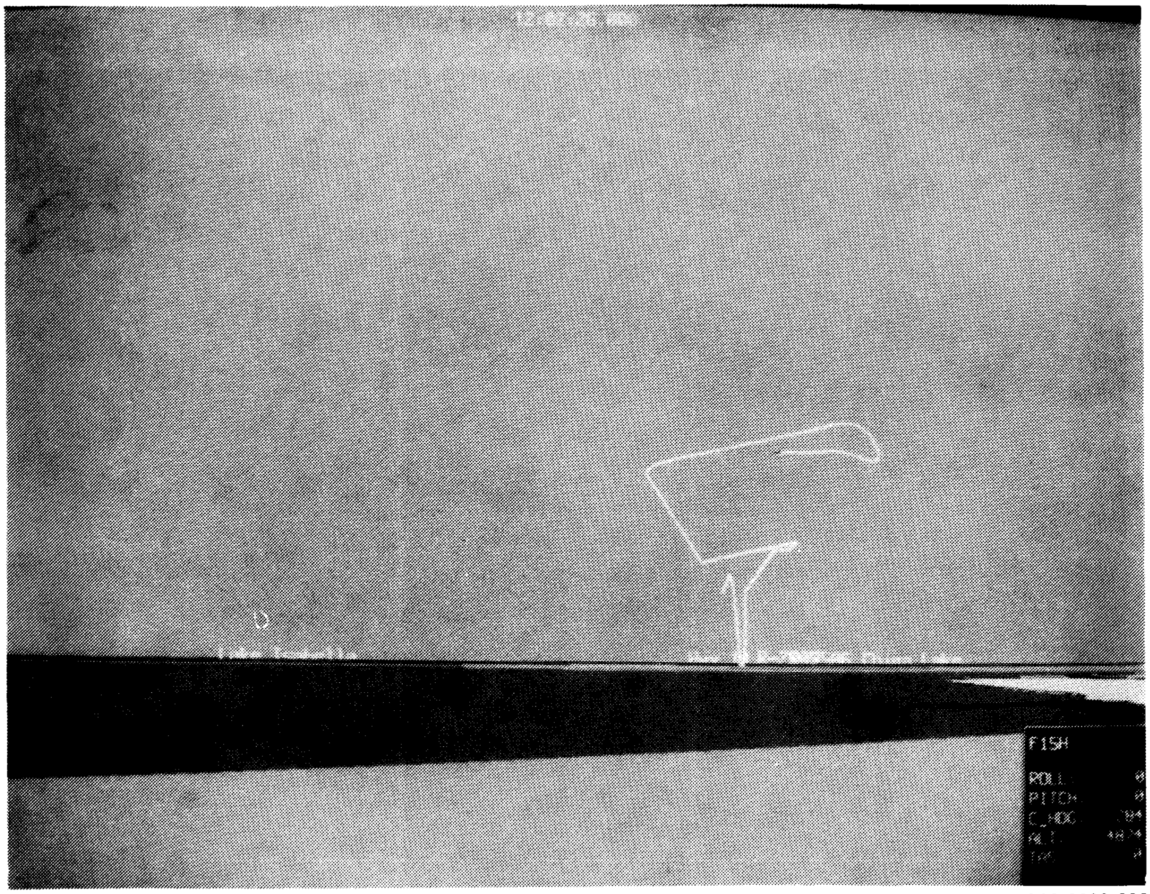

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Figure 10. RIM display, ground view.

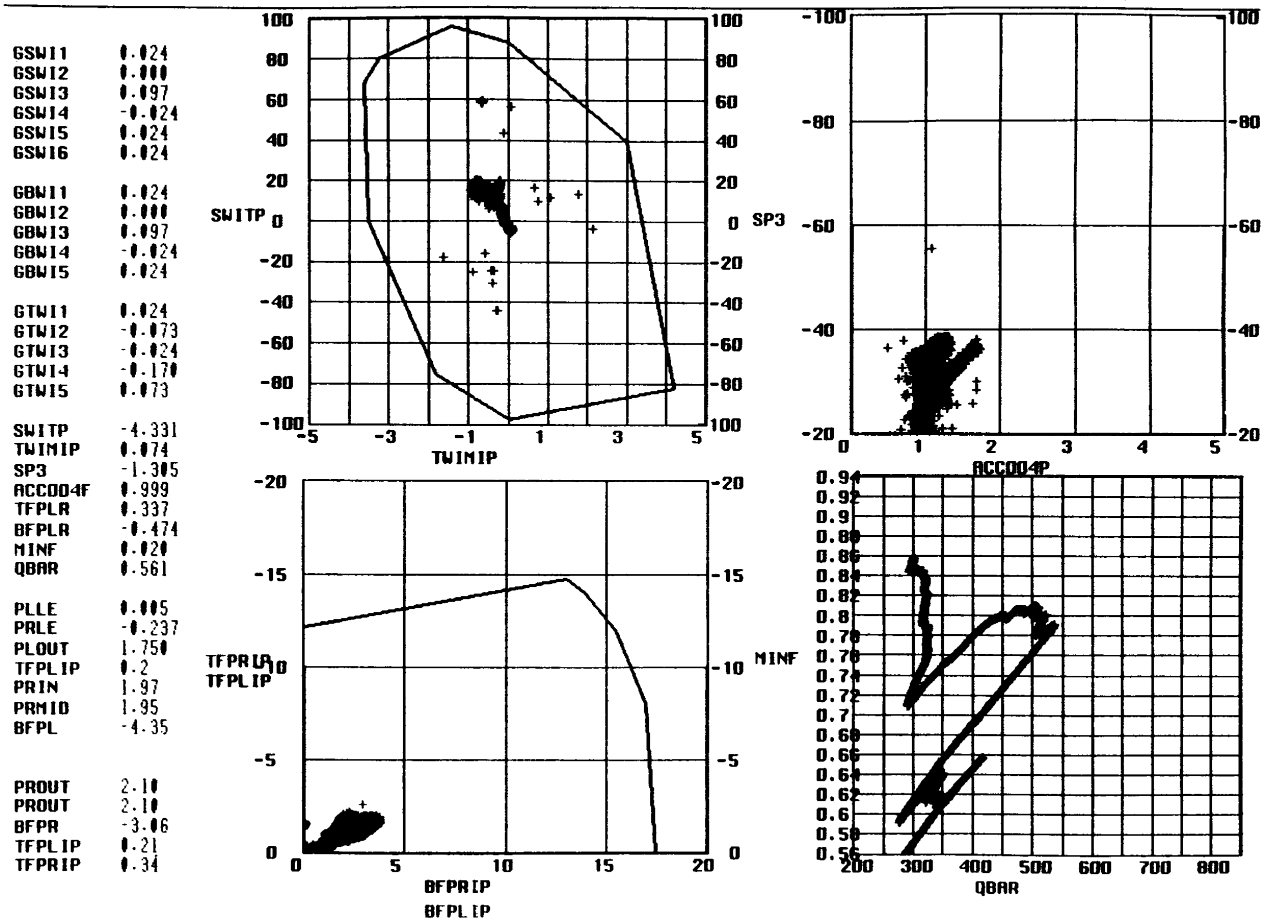

Figure 11. MAGIC display with graphics and digital parameters.

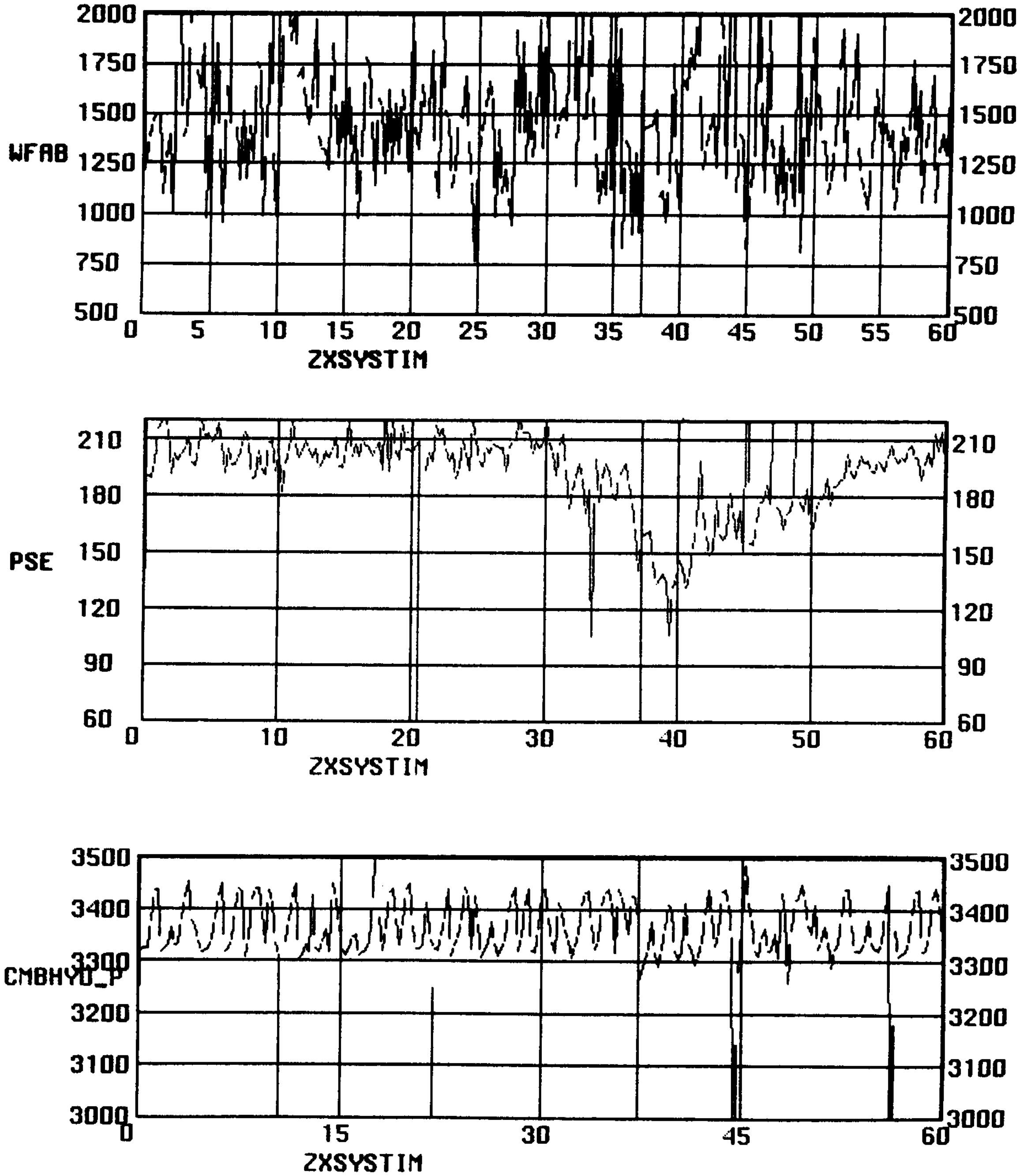

Figure 12. MAGIC display time history plots.

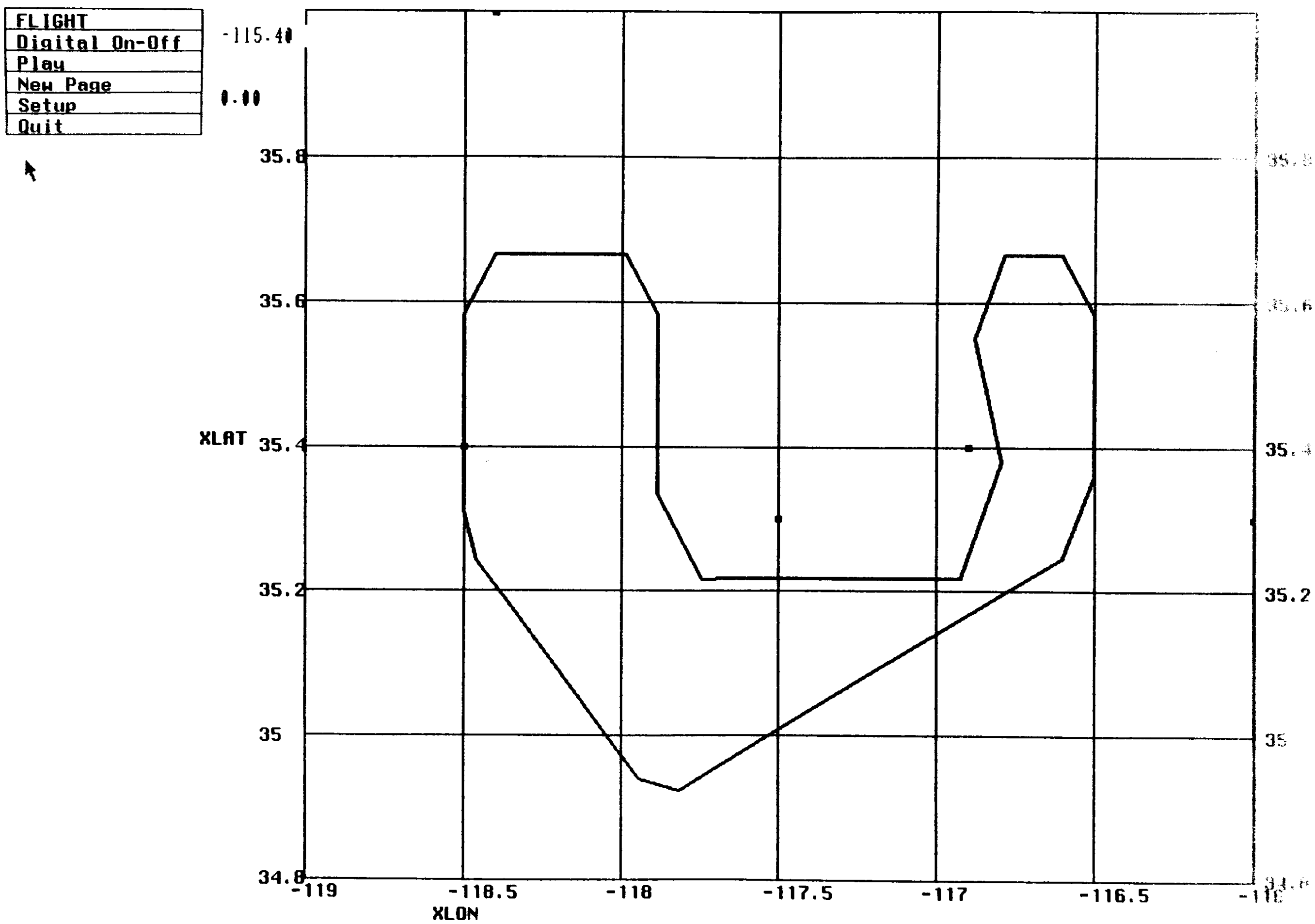

Figure 13. MAGIC display with polygon overlay.

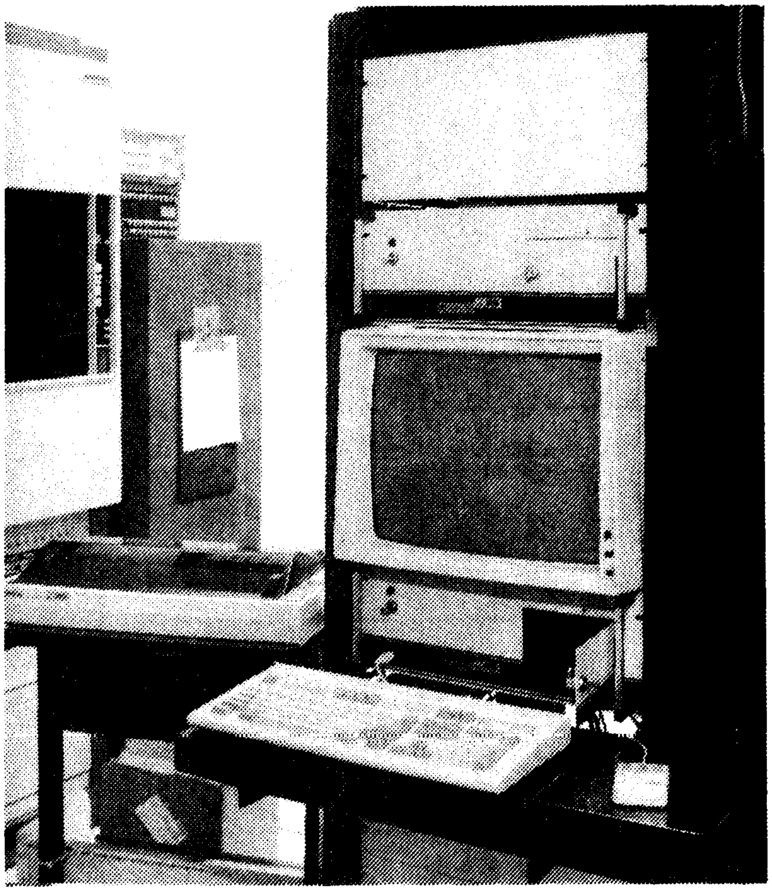

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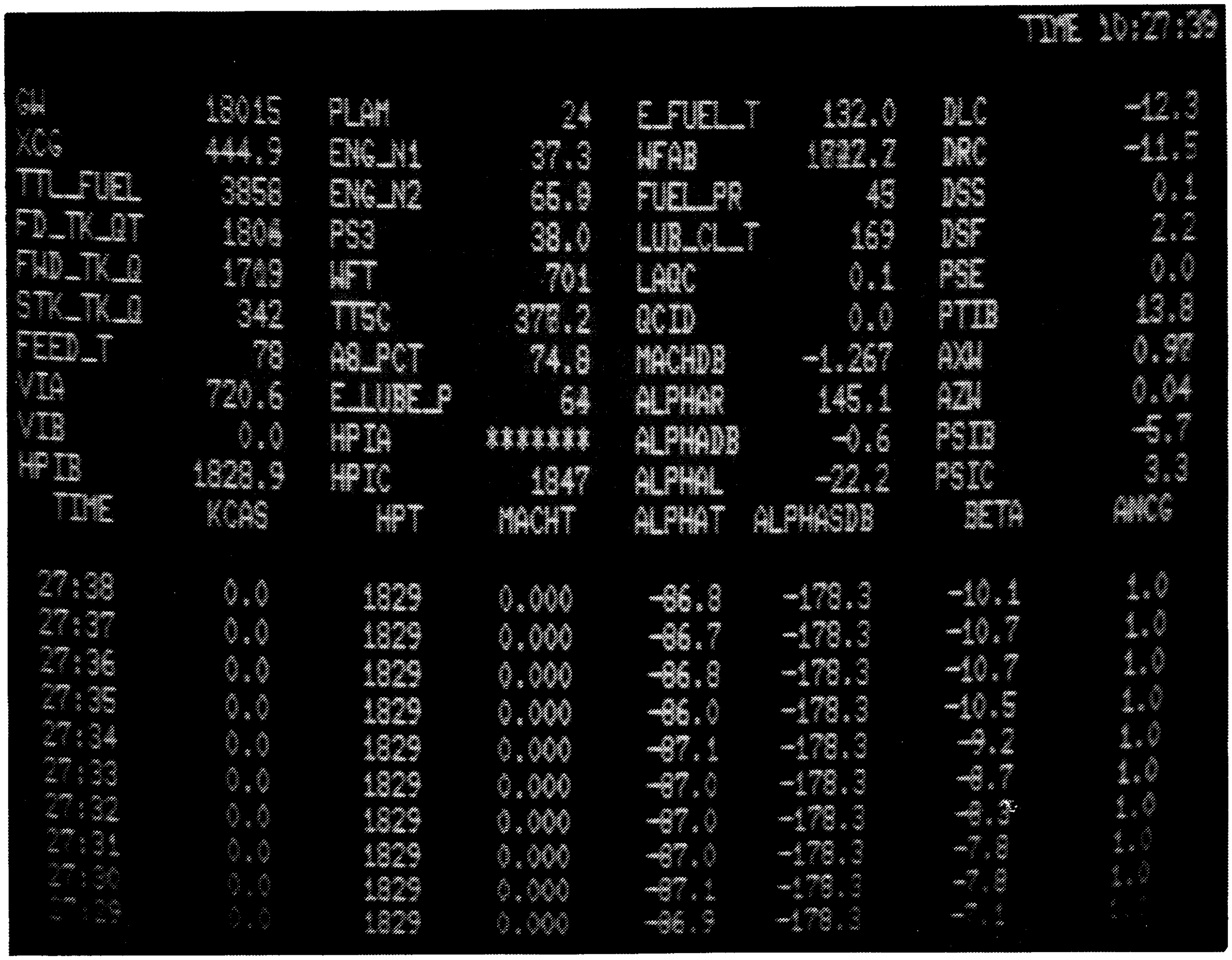
Figure 14. Real-time interactive PC/AT compatible workstation.



EC88-0006-004

Figure 15. ANCRT display.

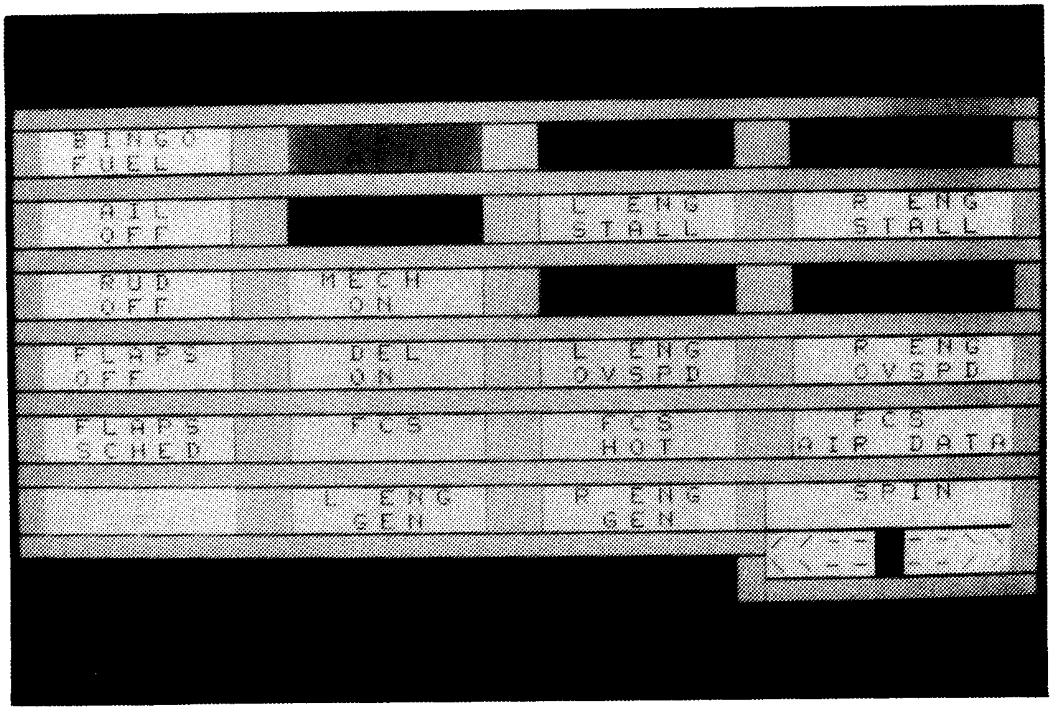


Figure 16. Color panel display.

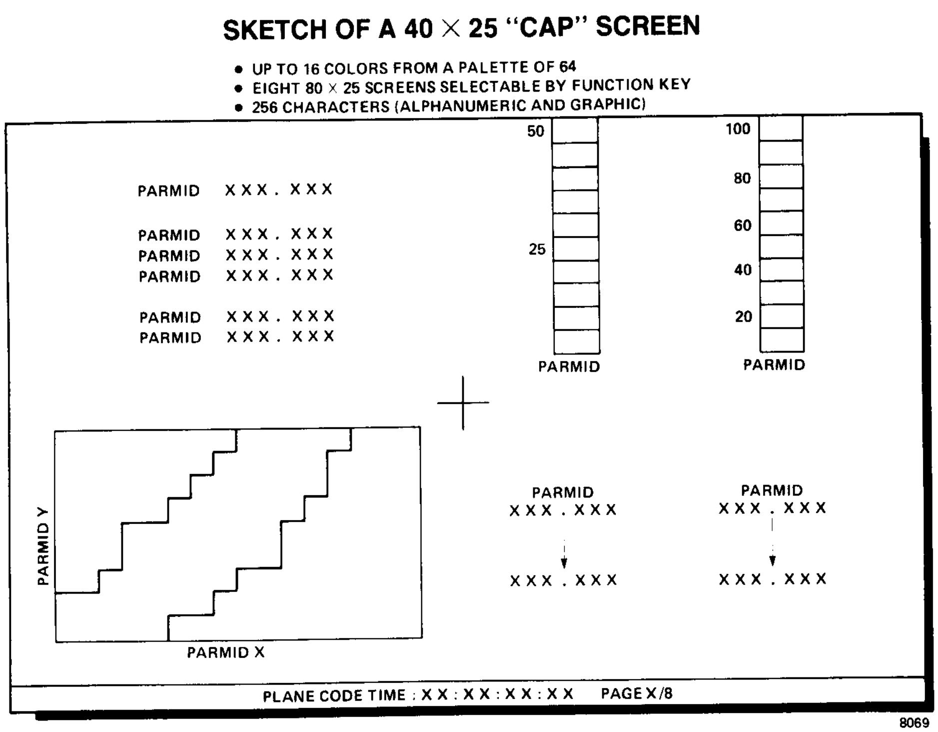


Figure 17. Alphanumeric data and color panel graphics in quarter page formats.

DSPLAY FLOWGRAM

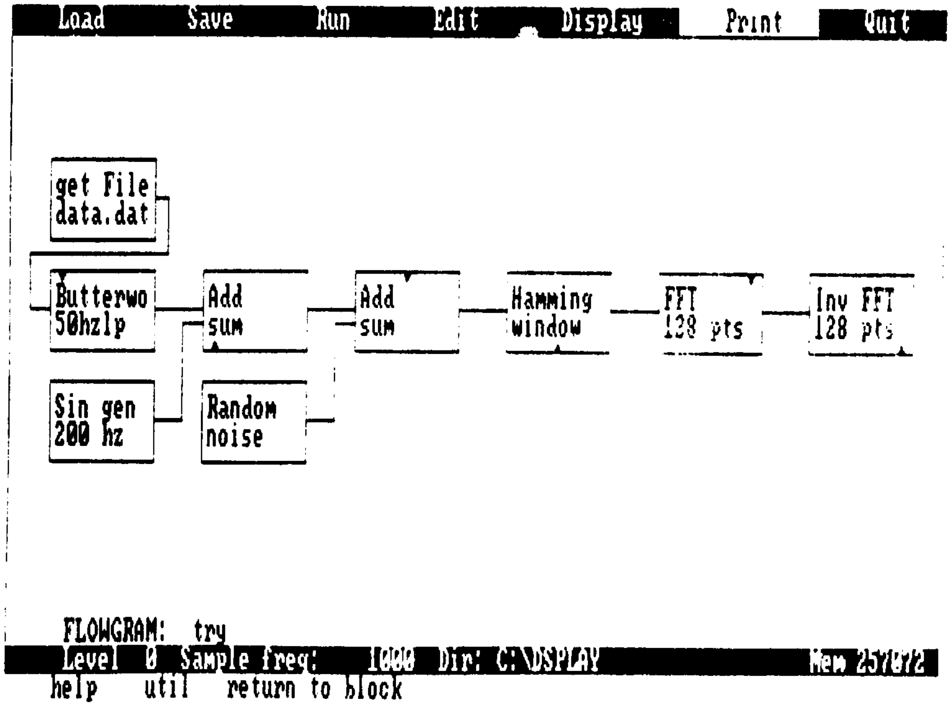


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Figure 18. DSPlay flowgram.

DSPLAY DISPLAY

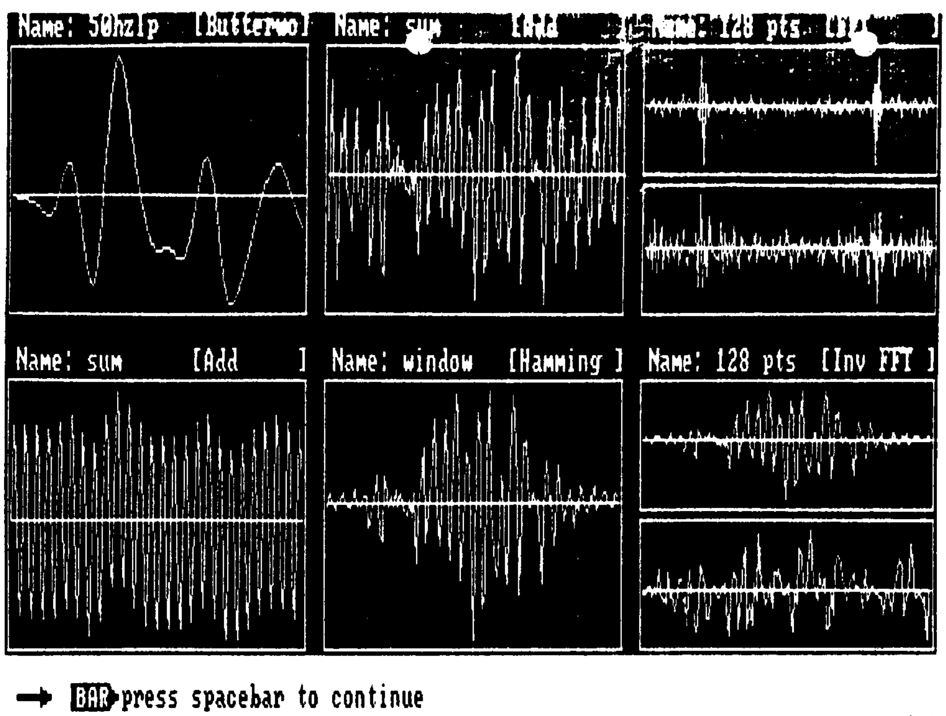

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Figure 19. DSPlay display.

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15. Supplementary Notes

The authors plan to hand out this report for more detailed information during a poster presentation at AIAA 27th Aerospace Meeting, Reno, Nevada, January 9–12, 1989.

16. Abstract

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