DISPLAY TECHNIQUES

by

S F Meatcher
Admiralty Underwater Weapons Establishment
Portland, Dorset, England

ABSTRACT This paper sets out to review current sonar information displays and to indicate how technological advances over the past decade lead to the concept of a common information display console.

To appreciate the problems involved a brief insight into the nature of the information to be displayed in shipborne systems is given, from which is derived a summary table of the basic display parameter requirements. It is shown that the wide variety of data types required to be displayed may be reduced to a small family of display categories, leading to the conclusion that it should be possible to implement a display system which is sufficiently flexible to be reconfigured dynamically to any category.

An additional requirement for sonar displays is that the operator should be able to interact effectively with the system via the display. Accordingly a discussion is included of current interactive devices together with their advantages and disadvantages.

To examine some of the problems of sonar information display an experimental system was procured in 1975 by AUWE and the salient features of this system are briefly outlined. Much of the work with this system has been on the problems associated with formatting of the sonar data for display and, by way of illustration, some of these formats are presented, together with their potential benefits and problems.

Although much valuable experience has already been gained, a number of questions remain unanswered, particularly those relating to the use and scope of modern display techniques. A new experimental facility being acquired by AUWE is described. This will be used to examine the practicality of the common display console approach.

INTRODUCTION

Shipboard systems utilising a display of some kind to interface between the machine and the operator have, in the past, been designed to match the display to the data output from the system and utilised the most convenient technology to implement the display functions. This had led to a proliferation of display device types and the consequential problems of logistic support, training needs and inflexibility.

Much work has been carried out at AUWE to resolve the problems associated with shipborne displays with the aim of formulating a coherent policy for future display systems.

DATA TYPES

The first step in this process was to look at the various equipments in use and note the type of display format used to present the data to the operator. The summary of data types shown in Fig 1 gives some indication of the wide range of displays in a modern ship.

ACTIVE SONAR	PASSIVE SONAR	AIO/FC	OTHERS
B SCAN PPI A SCAN OVERLAYS LIBRARY COMPUTER- MARKERS TOTE CURSORS	TIME/BEARING TIME/FREQUENCY SPECTRA THREAT LINES LIBRARY COMPUTED TRACKS CURSORS	LPD TOTE BOA F C SOLUTION WEAPON STATUS PREDICTIVE DISPLAYS	BATHYTHERMOGRAPH RAY TRACE ECHO SOUNDER PERISCOPE NAVIGATION M/C STATUS SHIP STATE RADAR INTELLIGENCE ECM

FIG 1 TYPES OF DATA TO BE DISPLAYED

If one extracts the parameters required of a display system to implement these varius formats, the problem of minimising the variety of display types begins to appear a little more tractable.

	REQUIRED CHARACTERISTICS					
SENSOR	MULTI GL	HIGH RESOLUTION	CHARACTERS	MULTI-SCREEN	OVER-LAY	WATER-FALL
ACTIVE SONAR	O	O	O	O	O	
PASSIVE SONAR	O	O	O	O	O	O
AIO/FC		O	O	O		
B/T			O			
RAY TRACE			O			
ECHO SOUNDER	O					O
PERISCOPE	O	O			O	
NAVIGATION	O	O	O		O	
M/C STATUS			O			
SHIP STATE			O			
RADAR		O	O		O	
INTELLIGENCE			O			
ECM	?	?	?	?	?	?

FIG 2 DISPLAY REQUIREMENTS FOR VARIOUS SENSORS

Fig 2 shows, in general terms, the characteristics required in a display and it is apparent that a display system which combines the features of multi-grey level, resolution, and multi-screen with the ability to generate characters, scroll data and overlay data would fulfil virtually all identifiable shipborne display requirements. The design process for such a display system required that we first consider what display techniques were available to us, or likely to become available in the foreseeable future. A review of the wide variety of display techniques was carried out [1] , the results of which are summarised in Fig 3.

TECHNIQUE	ACTIVE SONAR		PASSIVE SONAR		QUALI-TATIVE	QUANTI-TATIVE	STATUS
	SURV	CLASSN	SURV	CLASSN			
PAPER	X		X	X			
FILM	X						
LONG PERSIS-TENCE CRT	X	X					
REFRESHED CRT	X	X	X	X	X	X	X
PLASMA					X	X	X
ELECTRO-LUMINESCENT	O	O	O	O	X	X	X
LED						X	X
LIQUID CRYSTAL	O	O	O	O	O	X	X
LIGHTS							X

(O - Techniques which may become available in the future
X - Techniques currently available

FIG 3 DISPLAY TECHNIQUES

The display requirements are shown as the five distinct categories to which data types may be reduced. viz:

Surveillance - Raw data output from active or passive sonars, probably with some form of overlay.

Classification - Processed data.

Qualitative - Situation display, graphics.

Quantitative - Alphanumeric displays giving factual information such as range, bearing, depth etc.

Status - System condition eg Ready/Not Ready, Open/Closed.

Of the categories shown, surveillance and classification require a grey-level capability whilst the others are normally single level.

It is evident from this survey that the only technique currently available which fulfils all of the requirements is the refreshed CRT. There are, however, two modes in which the refreshed CRT may operate - cursive or raster scan - and it is worth looking at their relative merits. The cursive mode requires three inputs - X, Y and Z - to drive the spot around the screen. Data is time serial and the more complex the picture the longer it takes to write and hence the lower the refresh rate. If overlays in the form of charts, alphanumerics, computer markers etc are required, these have to be time-division multiplexed with the data, reducing the refresh rate still further. The raster mode has a spot scanning the screen repeatedly in a regular fashion. Only Z input is required to brighten the screen at the desired X and Y co-ordinates but Z input must be synchronous with the scanning sequence. If overlays are required they may be readily mixed with the incoming data stream with no modification of the refresh rate, but again the requirement for synchronism exists. The more important differences between cursive and raster are summarised in Fig 4.

CURSIVE	RASTER
REFRESH RATE VARIES WITH DATA	REFRESH RATE CONSTANT
OVERLAYS REDUCE REFRESH RATE	NO EFFECT
BRIGHTNESS VARIES WITH DATA RATE	BRIGHTNESS CONSTANT
REFRESH MEMORY SIZE $\propto$ DATA	REFRESH MEMORY SIZE $\propto$ RESOLUTION
SCREEN RESOLUTION INDEPENDENT OF BANDWIDTH	RESOLUTION $\propto$ BANDWIDTH
DIFFICULT TO MIX INDEPENDENT PICTURES	EASY
INTERACTION STRAIGHTFORWARD	INTERACTION MORE COMPLEX

FIG 4 IMPORTANT DIFFERENCES CURSIVE/RASTER

To achieve the display requirement for a completely flexible work-station all these factors have to be considered and on balance a raster modesystem is favoured. Other factors which influence the choice of raster-mode are:

Ease of transmitting complete pictures around the ship - only a single coaxial cable is required.

Video switching and video mixing are well tried and tested techniques in the commercial world and have considerable potential for shipboard use. For example, displays from any source (eg active sonar) may be routed, on demand, to any other operator (eg passive sonar) as an aid to his decision making process.

Pictures from remote cameras for navigiation or machinery monitoring may be simply called up for display at any workstation as and when required.

FIRST EXPERIMENTAL SYSTEM

For the research stage the decision was taken to adopt, initially, the UK television standard of 625 lines largely to take advantage of commercial developments. Accordingly a specification was drawn up in 1974 for an experimental display facility. This system (Fig 5) basically comprised on twin digital data disc used as a picture memory, together with the associated electronic circuits to format and buffer data, generate timing signals and control data transfers between CPU and discs. The system generates pictures with an interlaced raster of 625 lines at 50 fields/sec refresh rate. Each line comprises 416 cells which, together with 584 visible lines, gives a total screen area of some $\frac{1}{4}$ million pixels. Each picture may be programmed to have an intensity range of 2, 4, 8 or 16 levels. The total system storage capacity is 8 full pictures of 16 grey levels and proportionally more at lower intensity ranges. The disc memory is organised as two separate stores referred to as "Back-up" and "Video". Picture data is written to the back-up disc one TV line at a time and when a picture is complete it may be transferred to the video disc. Since disc read amplifiers tend to saturate when a disc is being written a picture displayed from this disc shows a characteristic white line across the screen at the current write line address. An undisturbed picture is obtained by displaying from the video disc until a picture has been completely assembled on the back-up disc and then transferring a complete picture from back-up to video. Whilst the process of writing the video disc is continuing the display is automatically enabled from the back-up disc.

FORMATTING DATA

Much of the work with the experimental system has been directed towards formatting active sonar data for 625 line raster-scan display, although some work has been carried out on passive and AIO displays. The data base used for the active work came from two active sonar systems. One was a long range, dual ping, multi beam, doppler detection system, the other was an experimental long range, high resolution sonar. A large number of data tapes were recorded, at sea, under a variety of typical operating conditions.

There are a number of problems arising from the use of conventional long persistence CRTs for displaying long range active sonar information. The operator requires to view the display constantly if he is to observe all signals before they fade, and this leads to vigilance problems. In addition there is little scope for re-examining returns within the ping duration. Initially, therefore, efforts were directed to producing a display whereby all the returns from a single ping were stored, the display refreshed at 50 Hz from the stored data, and all the data from that ping presented to the operator with individual intensity levels preserved until overwritten by data from the next ping. The benefits

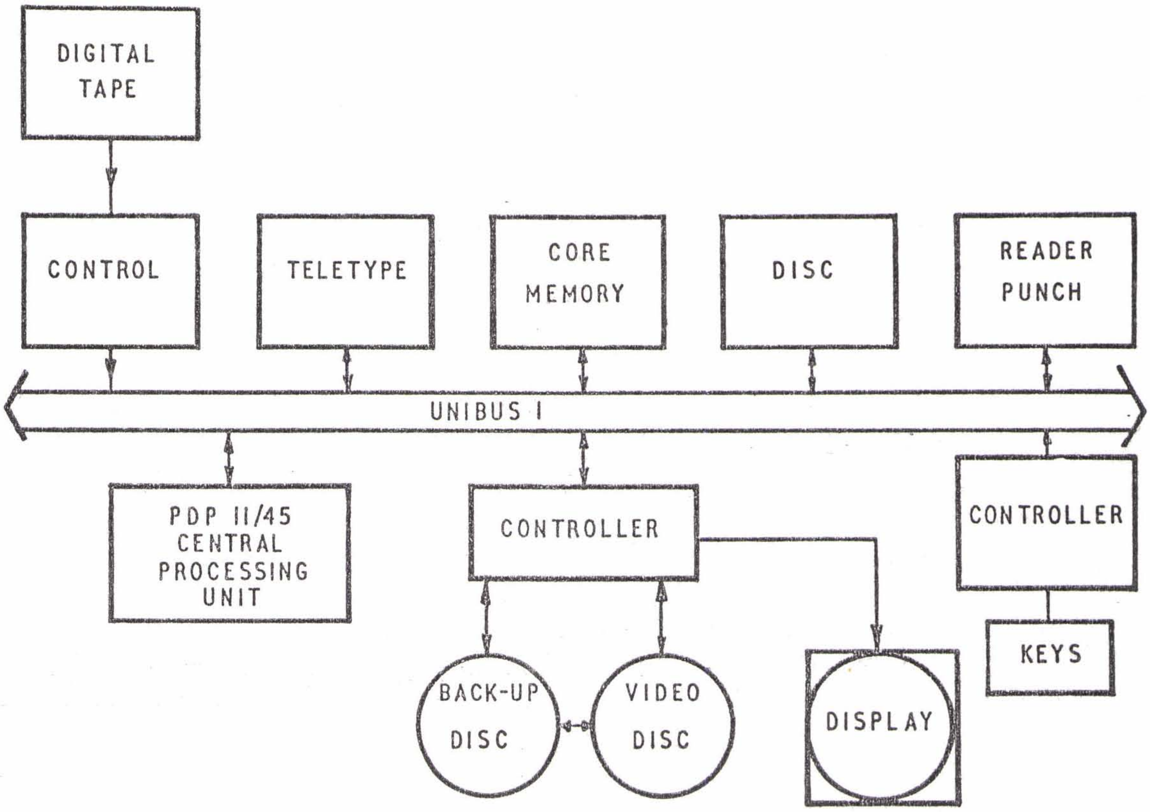

FIG. 5 DISC BASED DISPLAY SYSTEM

from this to the operator are immediate and fairly obvious. He is no longer constrained to following a crawling line to detect targets, he can scan the screen at random, and, because relative intensities are preserved, tracking is much simplified.

An important outcome of these very early efforts was to demonstrate the feasibility of formatting data for refreshed displays in real-time and to get some idea of the amount of computing effort involved. It was shown that there would be no severe requirements in terms of speed, power and size of memory.

A powerful aid to detection for a surveillance display operator is the provision of a historical record of what has happened on previous pings. One of the earlier attempts at this is shown in (Fig 6). Here the output from 8 beams are displayed parallel to each other. Within each beam a history of the last 8 pings is displayed with the oldest ping to the left and the current ping to the right. Using this technique tracking targets stand out very clearly and are easy to detect but bottom reverberation also produces many track-like marks which can lead to an undesirably high false alarm rate. This technique does, in fact, compress the raw data and deprives the operator of many of the clues which are available to him from the simple refreshed display. It appears prudent therefore, when using this format, to display the current ping, in full, adjacent to the history display. Other formats which combine the advantages of history with low false alarm rate have been devised and are currently being evaluated for fleet use.

An interesting example of how dramatic improvements may be made to very cluttered sonar displays is shown in (Figs 7 and 8). (Fig 7) shows the output from a dual ping, ripple transmission, doppler sonar. The axes are, range in Y, beam number in X, doppler channel within each beam, while between each beam is displayed the returns from a second, shorter, ping. The first point to note is that, because the system has a ripple transmission, returns from any target which appear in adjacent beams do not have the same Y co-ordinate on the screen and the returns from the second,short, ping are staggered further. This makes it difficult for the operator to correlate returns from a common target. Once the capability to store all the data is provided it is but a trivial exercise to introduce the appropriate range corrections. However, for this sonar, we wanted to go a stage further and to include the benefits of a history display and, at the same time, to capitalise on the fact that, being a dual ping sonar, there existed two independent samples for each range increment on every transmission. For each transmission, at each range increment, and for each beam, the maximum level from any doppler channel within a beam was extracted, stored,and displayed as range in Y against beam number in X. Displayed adjacent to this and to the right is the short ping data. On successive transmissions the doppler data is displaced one pixel to the left and the short ping data one pixel to the right, with the new data written into the original positions. The result of this is shown in (fig 8). This format is called "Arrowhead" for fairly obvious reasons, closing targets produce an arrowhead pointing down whilst receding

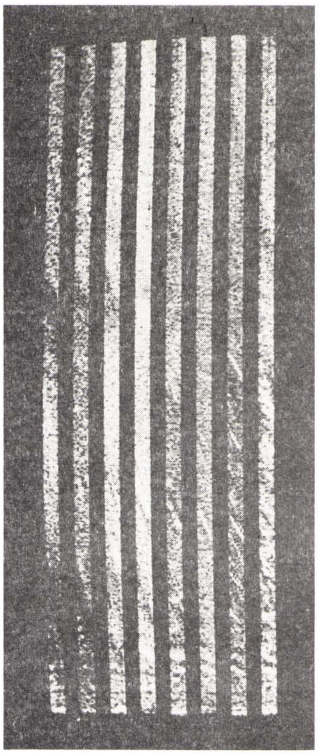

FIG. 6 BEAM HISTORY FORMAT

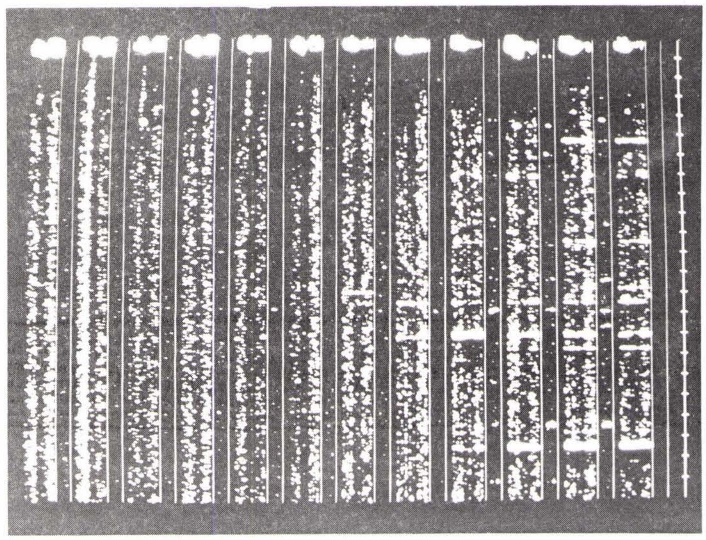

FIG. 7 DUAL PING DOPPLER SONAR

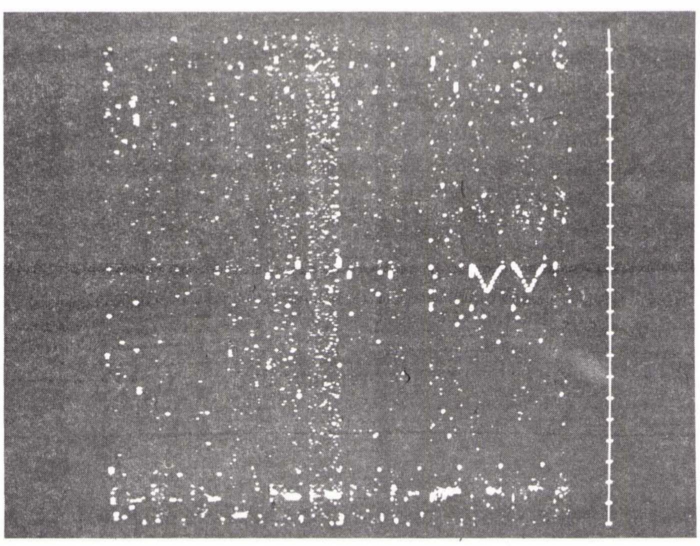

FIG. 8 ARROWHEAD

targets produce an arrowhead pointing up. This technique would also appear to have applications in situations where more than one sonar is in use.

INTERACTION

An operator must be able to communicate with a system to extract or inject information, modify the mode of operation, to initiate tasks or to perform tracking activities. There are many ways in which an operator may communicate with the system and it is incumbent upon the display designer to ensure that the interactive device chosen is optimised for the task in hand. An indication of the range of interactive devices currently available is given in fig 9.

DEVICE	CHARACTERISTICS
DIGITISER	Display mounted. Continuous or discrete steps. Good spatial selection, flexible good feedback correspondence.
ISOMETRIC JOYSTICK	Force operated, robust, suits tracking/positioning tasks.
ISOTONIC JOYSTICK	Displacement operated. Suits tracking/positioning tasks.
KEYBOARD	Fixed format, accurate, fast after training.
LIGHTPEN	Good spatial selection, flexible, good feedback.
PUSHBUTTONS	May be grouped like keyboard or around display to perform like discrete digitiser.
TRACKBALL	Alternative to joystick, ballistic/continuous, fast accurate.
ROTARY CONTROL	Cheap, compact, single variable.
SPEECH INTERPRETER	Hands free, complex, potentially good for data selection tasks.
TABLET	Continous, compatible with pen and paper, spatial selection depends on output device.
SWITCHES	Cheap, simple, good feedback, inflexible.

FIG 9 INTERACTIVE DEVICES

There is, unfortunately, no simple definitive way in which input devices for interactive tasks may be selected, there is inevitably some trade-off. A report by EMI Electronics, England [2] highlighted some of these difficulties. It was shown that, whilst speed and accuracy of various devices could be assessed for simple activities such as selection, position, inject, the speed with which a procedure was performed was heavily dependent upon the design of the procedure itself. Also the results depend to an extent on what activities precede and succeed the procedure, and on the likely extent of errors occuring during the procedure and the time taken to correct them.

If, as seems likely, more than one device is needed to perform all the tasks required of future workstations, then consideration must be given to the way in which devices may, or may not, complement one another. It will not be sufficient to simply optimise a procedure for a given input device or to select what appears to be the most appropriate device for a given task without due consideration of the way in which the choice of device, or design of procedure, influences other procedures. Consider, for example, a procedure which contains largely tracking/ positioning type activities (for which a joystick may be the most suitable device) but which has some limited selection activity (for which a light pen may be more suitable). Analysis may show that the best overall efficiency for this particular procedure is achieved by using the joystick for both tracking and selection activities since no device selection overheads are incurred. If, however, the operators duties also include procedures which are composed largely of selection type activities then, should such a procedure follow the previous procedure, a change of input device may be thought appropriate for best device/ activity match. This could cause problems for the operator, however, in terms of increased stress and momentory disorientation which may outweigh the advantages of choosing what would appear to be the optimum interactive device. The designer must be aware of these problems and ensure that the operators task as a whole is considered. In the absence of any precise design rules this could well involve many iterations of procedural design.

FUTURE TRENDS

Many questions remain to be answered with regard to workstation design of which a large proportion are inter-related. For instance:-

What is the optimum resolution in terms of pixels/display area?

How many screens should be used, what size, how should they be juxtaposed and how should the data for any given task be distributed around the available screens?

Which aspect ratio best matches data display and interactive requirements?

What is the minimum number of types of interactive device required to support foreseen interactive tasks?

It does seem clear, however, that for the display itself there is unlikely to be any serious contender to the CRT in the immediate future and that semiconductor RAM is the most likely technology for picture refresh memory. It was with these thoughts in mind that a new experimental facility for AUWE was proposed. The system [Fig.10], currently being built by Sigma Electronic Systems of Great Britain, has the salient features of:

Intelligence
Graphics Memory
Large pixel address range
Variable organisation of pixel memory in X, Y and Z
Display resolution up to 1024^2 pixels
Interactive processor supporting several interactive devices

The intelligent part of the system responds to coded instructions from the host processor to perform display orientated tasks such as vector drawings, character generation, pixel plane allocation, masking, initialisation and bit packing and unpacking to pixel memory. In addition it will run graphics programs stored in its own graphics memory, as a series of instructions, upon receipt of a single 'GO' command from the host processor.

The pixel store is conceptually 32 planes of 4096 x 4096 pixels with the physical semiconductor RAM, pixel memory of user size (say 512 x 512 or 1024 x 1024) relocatable anywhere within this range. The total capacity of the system will be constrained at present to about 48 Mbits by physical limitations.

The interactive processor enables the user to define and run sophisticated interactive tasks with minimum overheads on the host processor.

This experimental facility will be used intensively over the next two years to enable AUWE to produce a design for a general purpose workstation which will form one of the major building blocks of all future shipborne systems.

REFERENCES

1. MORRIS J C. 'Integrated display concepts for future generation submarines'. Publication 44997 (Restricted) AUWE, Portland, Dorset, England, 1978.

2. RUMENS D J. 'Ergonomics for future submarine systems: Documentation of human performance data on specified input/output devices. MEMO No 451 VOL I. EMI Electronics Ltd, Systems and Weapons Division, Feltham, Middlesex, England, 1978.

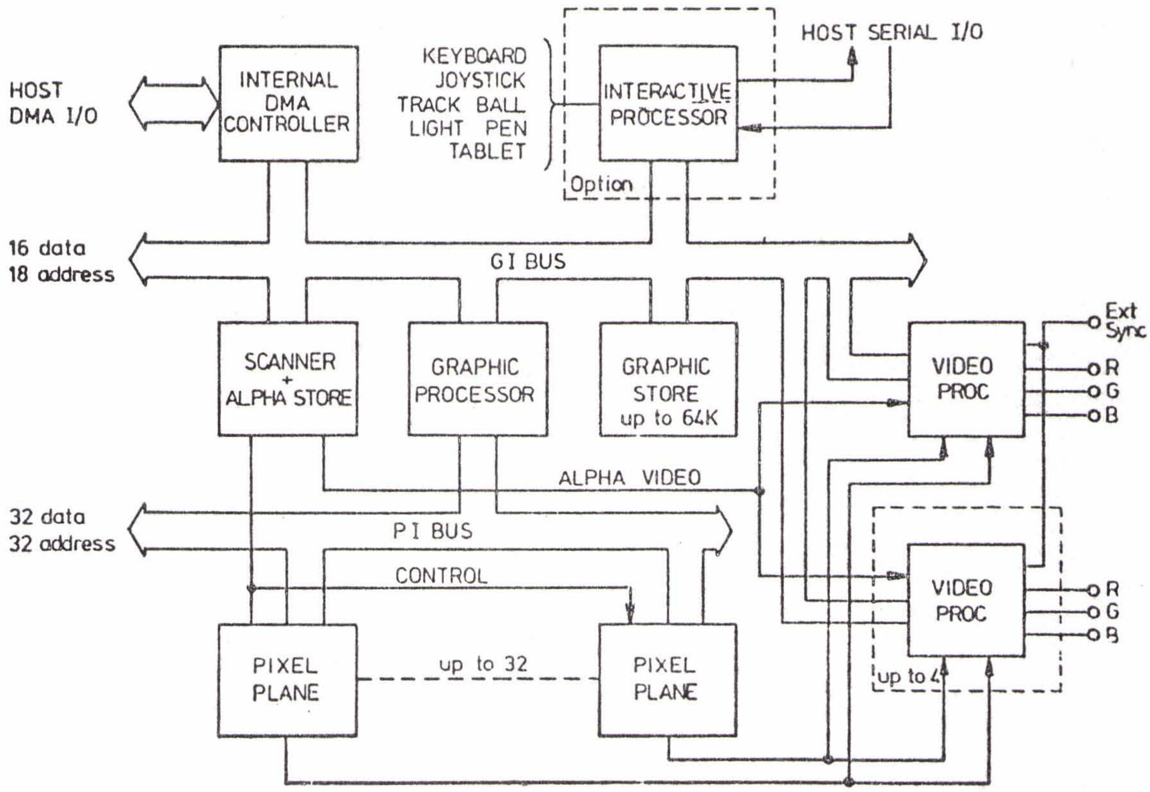

FIG. 10 NEW EXPERIMENTAL FACILITY

DISCUSSION

E. Cernich For a given display system and a number of functions that the operator has to perform on the displayed data, what is the criteria to select: to give the commands by specialized keys or by a keyboard?

S. Meatcher It is not intended that there should be any dedicated keys on the common console. If keysets are used it is intended that their functions should be redefinable under software control, i.e. they will be used as "soft" keyboards.

CAPT A. Newing Is it the intention to restrict the generalized work station to sonar applications or to make it applicable to all sensors and shipboard displays?

S. Meatcher Initially our efforts will be directed to producing a common work station for all sonar and directly-related applications but other areas, such as machine monitoring and ship status, are not being ignored.

B. Pennoyer Please comment on the use of colour since it is missing from your list of parameters.

S. Meatcher At this point in time it has not been shown that the use of colour will confer any significant operational benefits. It is our intention to use monochrome displays until such time we are convinced that the use of colour is cost-effective. It should be pointed out that the two experimental systems shown will in fact support full colour displays.