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# DATA FUSION AND DISPLAY TECHNOLOGY FOR BATTLEFIELD HELICOPTERS

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PAPER - 13 DATA FUSION AND DISPLAY TECHNOLOGY FOR BATTLEFIELD HELICOPTERS

- ERRATA

Due to a misunderstanding Paper 13 was printed before correction of several typographical errors. Please note the corrections listed below.

Page 13-1 Second para - last sentence should read:
In a high threat environment a suite of ...

Page 13-2 First para, last sentence should read:-
...cockpit systems[1].

Third para, second sentence should read:-
The stated policy for ...

Page 13-5 Third para, first sentence should read:-
Use of colour has generally ...

Second sentence should read:-
A number of .....
..... systems monitoring formats.

Page 13-8 First para. should read:-
The red, green and blue signals are fed ...

Second para. should read:-
The biggest disadvantage ...

Page 13-9 First para, third and fourth sentences should read:-
The wheel was synchronised so that information of a particular colour was presented as the appropriate segment was in front of it. As the information was presented sequentially the refresh rate had to be trebled from 30 to 90 frames a second requiring an increase in bandwidth which was a problem at the time.

Page 13-12 First para, third sentence should read:-
... one of the parameters that are ....

Page 13-14 Fourth para. should read:-
Typical State of the Art luminance Levels[4] for ...

# DATA FUSION AND DISPLAY TECHNOLOGY FOR BATTLEFIELD HELICOPTERS

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## ABSTRACT

In future battlefield helicopters there will be an increased amount of data for use by the crew from a growing array of sensors. These sensors are associated with navigation, threat and target detection, self defence, and communications. The data presented raw would overwhelm the crew hence there is a need for mission management where data is filtered and outputs from different sensors are combined. Vital in the design of the mission system for future helicopters is an efficient Man Machine Interface and as part of this interface is display of consolidated and fused data. Potential display technology options include CRTs and Flat Panel displays. At the moment CRTs set the standard but have many disadvantages. Developments in Flat Panel displays are being made and once full colour, multifunction flat panels are available there will be a new freedom to exploit novel concepts and layouts. The totally enclosed cockpit with panoramic displays suggested as a means of reducing vulnerability to EMP and chemical and laser weapons may not seem far fetched.

## INTRODUCTION

Efficient operation of the battlefield attack or transport helicopter in the hostile environment likely to be encountered in a major conflict is increasingly expected to rely on data provided by a selection of sophisticated sensors and communications. This data will assist the crew and command to gain a satisfactory knowledge of enemy whereabouts and movement and then to act accordingly. Each system will have its own display and control requirements. At the same time it must be possible to operate day or night in good or bad weather and this will entail additional navigation and piloting display systems compared with those necessary for day fair weather conditions. In a high threat environment a suit of defensive aids is also highly desirable to, for instance, warn the crew of an enemy radar or of a missile approaching.

We can see therefore that to transfer data to the crew from systems enabling day and night operation at NOE with accurate navigation, to detect and identify and (for armed helicopters) to attack the enemy, while at the same time providing sufficient information of threats there will be a heavy demand for the available cockpit displays.

Table 1 lists candidate systems for battlefield helicopters which may need some form of display.

| | | |
|---|---|---|
| **Primary Flight Displays** | **Surveillance/Sighting** | **Defensive Aids** |
| **Piloting Aids** | IR | RWR |
| FLIR | Thermal Cueing Device | LWR |
| NVGS | TV | Hostile Fire Indicators |
| **Navigation** | Direct View Optics | Missile Approach Warning |
| Doppler | Laser Rangefinder/ Designator | Chaff / IR Dispenser States |
| INS | MMW Radar | IR Jammer |
| GPS | **Stores Management** | ECM |
| Map Display | ATGW | Obstacle Warning |
| Radio Aids | AAM | **Communications** |
| | Gun | UHF/VHF/HF |
| | Rockets | Data Link |

Table 1 Candidate Mission Systems for Battlefield Helicopters

Until recently when a new operational requirement or threat demanded new equipment the normal way of things was to add black boxes, any associated antennae or sensors plus controls and displays to the existing suite in the helicopter. Somehow this new equipment would be shoe horned into the machine. Figure 1 gives an indication of the growth rate in the number of cockpit systems.[2]

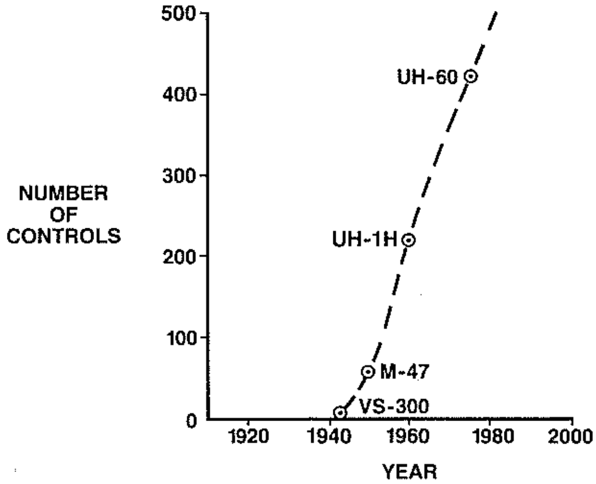



Fig. 1 Increase in Number of Controls for Various Helicopters

Sooner or later saturation point would be reached whether because of weight, space or crew workload considerations. The answer in the past has sometimes been to acquire a larger vehicle or to add additional crew members. A larger vehicle brings ith it undesirable features such as increased detectability and operating costs. Additional crew carry a large overhead in training and support.

The scene is now changing and we see a determined drive to use advances in electronics to reduce the size and complexity of subsystems and to use advanced processing techniques incorporating VHSIC, VHPIC and perhaps in the not too distant future artificial intelligence. The stated policy or the massive LHX programme in the USA is to aim for a single pilot vehicle by use of these advances. There is no doubt that the pilot will need every assistance possible if this is to be achieved whilst retaining adequate performance in the mission roles. Optimisation of the man machine interface will be vital.

At the last European Helicopter Forum the results of a paper study[2] of the benefits of advanced technology were presented by a delegate from the US Army Aviation Systems Command. The study covered the complete aircraft including structures and mechanical components as well as avionics. The combined benefits were startling. Using a baseline which looked akin to the Apache the advanced technology design had 59% smaller engine installed required power, 49% lower empty weight, 52% less mission fuel burned and 48% lower gross weight. The two most important technologies contributing to the reductions were the advanced technology rotor and the one man cockpit. Figure 2 shows the percentage reductions for each category as well as the baseline and aggregated technology details.

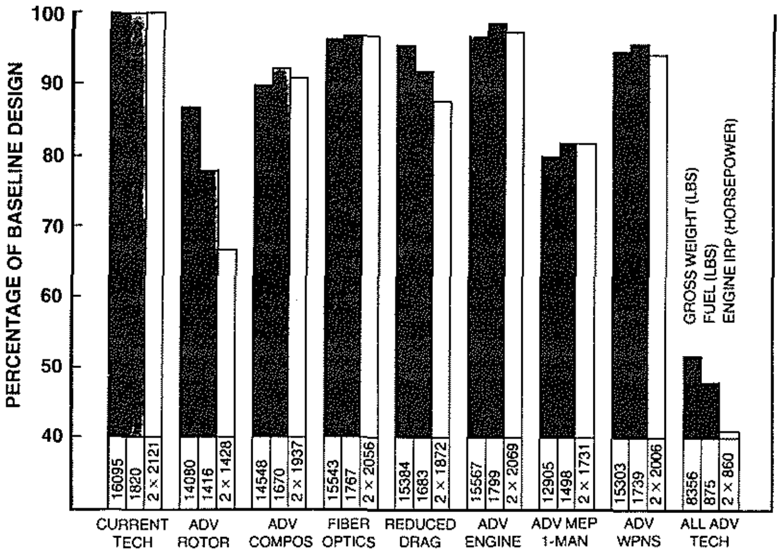



Fig.2 Advanced Technology Effects on New Battlefield Helicopter Design

In itself however, the use of new technologies of processing and miniaturisation will not alleviate the problems of the crew having to monitor, interpret and operate a large number of displays and subsystems. Figure 3 shows a traditional avionics architecture in which there may be a number of subsystems each with controls and displays and while it is possible to make some system elements more compact, lighter and more efficient the problem for the crew remains much the same. There will still be a heavy workload to interact with the system.

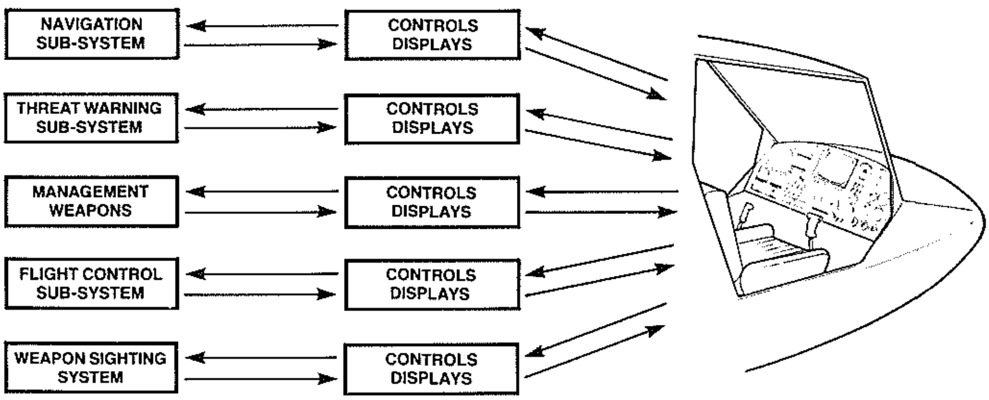



Fig.3 Traditional Avionics Architecture

Figure 4 shows the fused approach in which the data is integrated and may be displayed using fewer surfaces showing composite pictures.

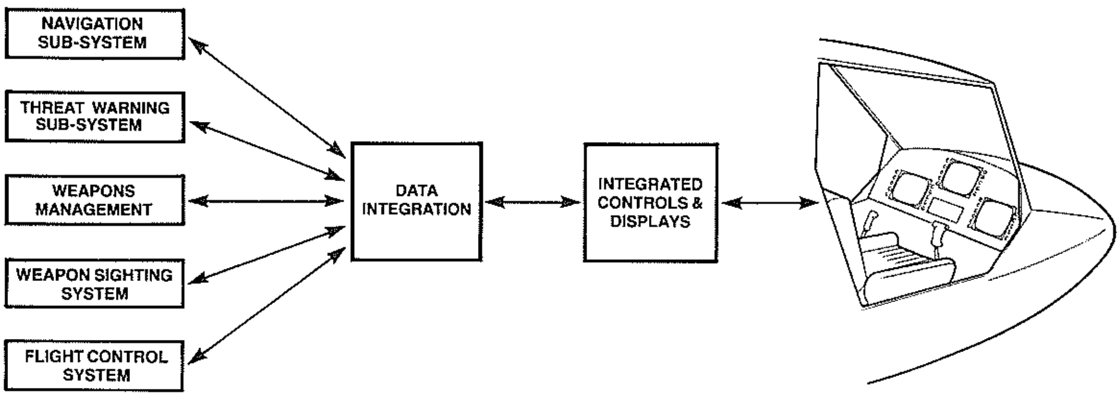



Fig. 4 Sensor Fusion Approach

This may be simply a map display with overlaid navigation symbology, mixing video with symbology such as for flight information overlaid on an EO sensor display or may be more sophisticated. Figure 5 shows on the left a low light TV picture of a group of trees which stand out well against the background. On the right is a FLIR image of the same scene in which the trees are difficult to distinguish against the background. However, some troops in amongst the trees show up well. Figure 6 fuses these two images clearly showing both the trees and the troops.

Fig. 5 LLTV Left FLIR Right Imagery of Same Scene

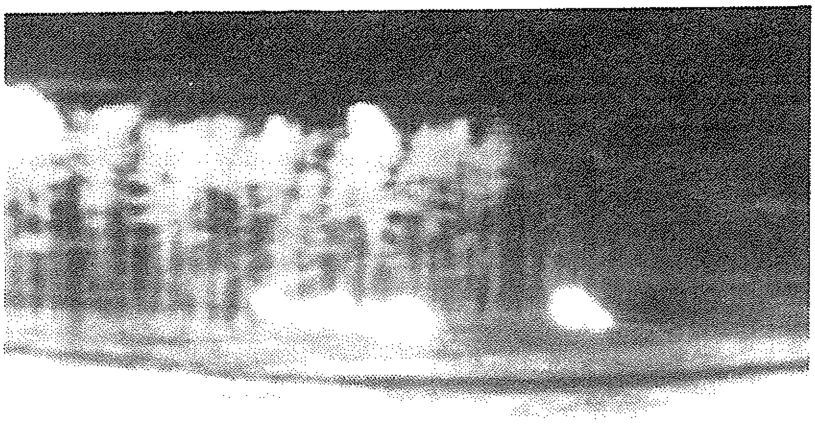


Fig. 6 Fused LLTV and FLIR Imagery

Given the mass of data which will be available a filtering process may be adopted to automate selection of displayed information dependent on the mode of flight thereby keeping clutter to a minimum. One step further and the computer interpreted data from one EO sensor could be used to direct a second sensor to scan a particular area automatically in order to confirm the presence of a probable target and then present the combined data to the pilot for action.

Besides displays showing fused data there are of course several elements which will provide the MMI improvements required in the next generation of aircraft including the options of voice, touch screen or keyboard input, voice output and the advances in computing to offload the pilot and allow him to make critical decisions without the distraction of mundane management tasks. The fusion concept will also apply here. Separate papers could be written on each of these subjects. The display suite is likely to be a complementary mix of helmet mounted and head down units but, the intention in this paper is to concentrate on head down multifunction displays and continue with a review of the technology available today and what the possible alternatives may be in the future.

Multifunction Display Requirements

Use of colour has benerally been accepted as an important method of coding displayed data for ease of detection and discrimination. A number ofr current civil aircraft sport colour CRT displays on the flight deck for presentation of flight, navigation and systems monitoring format. On the whole there is a standard set of information categories involved. The military requirement is more demanding and if fused displays are to be exploited will include full raster video as well as alpha numerics and graphics in various novel combinations. Therefore the ideal multifunction display should be capable of presenting these combinations and where appropriate in full colour.

CRTs

CRTs generally have disadvantages due to the depth required behind the panel, the weight of the glassware and the power required to drive them. Resolution of a conventional CRT is governed by screen size, brightness by the time the electron beam spends scanning a given area of screen. Increase of the screen size to provide better resolution results in a reduction in brightness because the scan covers a greater area in a given time. Slowing down the scan will result in flicker. In order to recover the lost brightness the beam current must be increased resulting in beam spreading and an increase in spot size which in turn reduces the resolution. Despite these problems, the CRT does a creditable job and although its demise has been predicted from some time, it will be with us for some years to come.

There are 5 types of CRT which are possible candidates for cockpit displays. These are:

Shadow Mask
Beam Penetration
Beam Index
Field Sequential
Channel Plate

## Shadow Mask

As shown at Figure 7a the shadow mask CRT has 3 electron guns - one for each primary colour. The beams from each gun are only permitted to hit corresponding red blue and green phosphor dots on the faceplate of the CRT. Control of the electron flow is accomplished by a shadow mask which has a hole in it for each triad of red/green/blue dots.

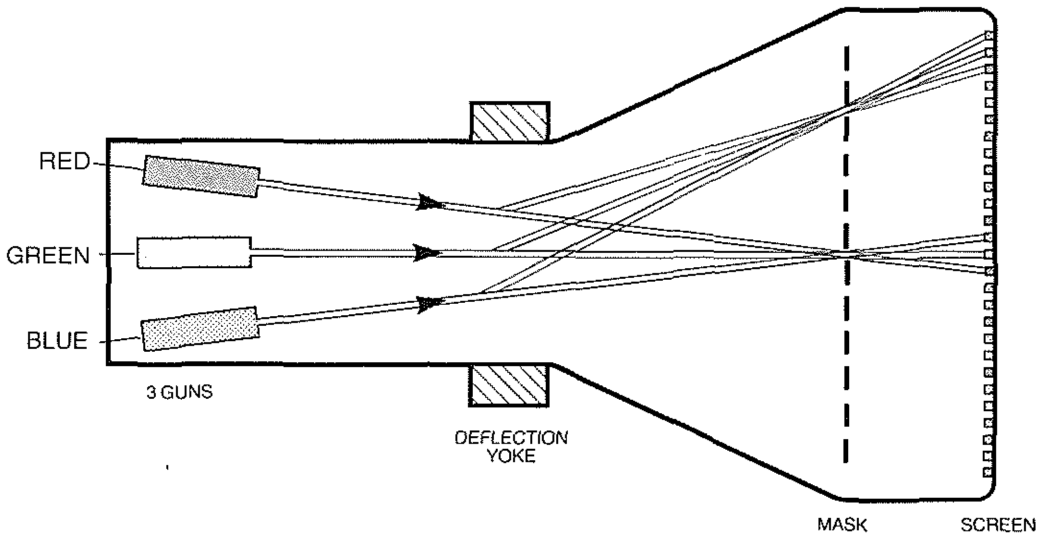



Fig. 7a Shadow-Mask CRT Schematic

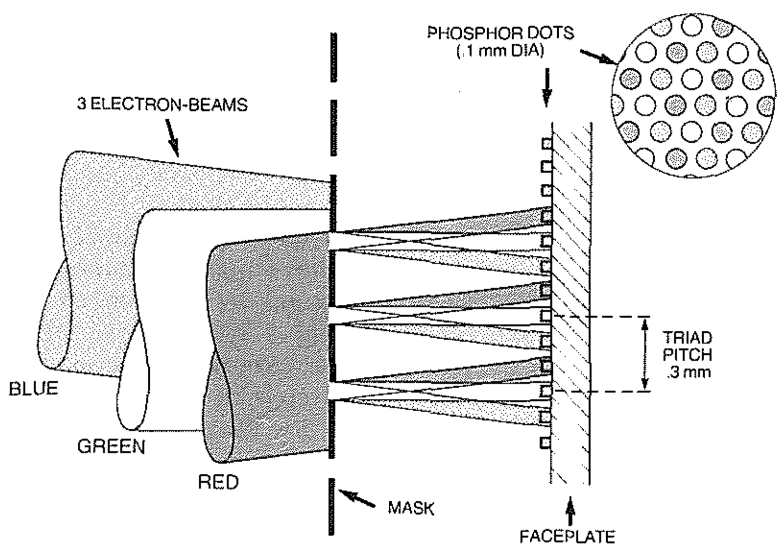



Fig. 7b Shadow-Mask/Screen Detail

The resolution of the display is limited by the pitch or spacing of the holes in the mask. This in turn is limited because sufficient mechanical strength and rigidity has to be retained to ensure the precise geometry is kept. The efficiency of the shadow mask is also limited because only 20% - 30% of the beam energy reaches the faceplate, the rest impinging the mask and heating it among other things. The mask may also be susceptible to magnetic effects. Improvements are on the way in the mask assembly which will allow higher beam energies and thus higher brightness without adverse heating effects.

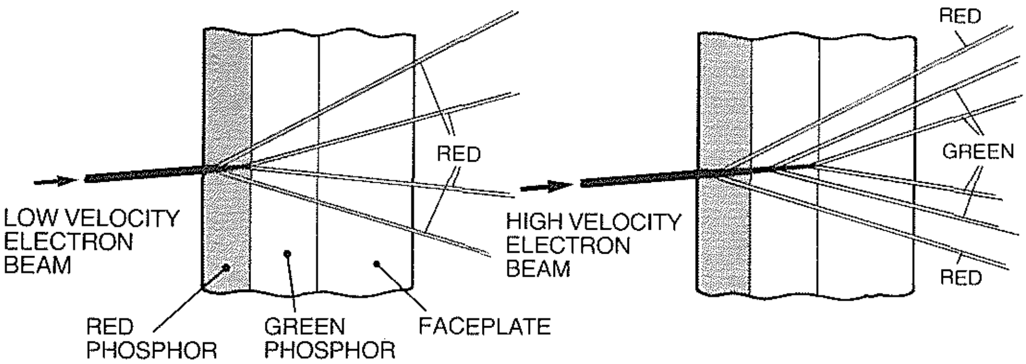
The advantages and disadvantages of shadow mask tubes are listed at Table 2.

| | |
|---|---|
| **Advantages** | Low Cost |
| | Mature Technology |
| | Raster/Cursive Capability |
| | Full Colour |
| **Disadvantages** | Efficiency |
| | Resolution Limited By Mask |
| | Convergence Of 3 Guns |
| | Susceptible To Magnetics |

Table 2 Shadow-Mask CRT Advantages and Disadvantages

Beam Penetration CRT

Figure 8 illustrates the principle of the beam penetration CRT. One electron gun is used to produce a beam which is directed onto two layers of phosphor at the faceplate.




**VARIATIONS –**
- Discrete phosphor layers
- Red and inert-coated green phosphor grains
- Red-phosphor coated on green-phosphor grains
- Single-gun tube
- Dual-gun tube
- Single-gun with P.D.A.

Fig. 8 Beam Penetration Screen

Red and Green are the usual phosphors. Using these a maximum of 4 colours - red, green, amber and yellow is produced. In order to switch colours the acceleration voltage has to switch from 18000 V to 24000 V (to penetrate to the second layer) and back again as required. High speed switching to produce changes at video rates is not practical at the moment. Hence most penetration CRTs are used in cursive (stroke) mode. If video is required it is produced in monochrome. Limited colour cursive writing may be achieved in the flyback period between raster frames.

The advantages and disadvantages of beam penetration CRTs are listed at Table 3.

| | |
|---|---|
| **Advantages** | Medium Cost |
| | High Resolution |
| | Efficiency |
| **Disadvantages** | High Voltage Switching |
| | Raster Only In Monochrome |
| | Limited Colour – 4 From 2 Primary |
| | White Not Available |

Table 3 Beam Penetration CRT Advantages and Disadvantages

## Beam Index CRT

The beam index CRT Figure 9 has one electron beam which scans red, blue and green phosphor stripes on the faceplate. The red, green and blue signals are fd to the beam in a rapid sequence exactly synchronised to ensure that their respective phosphor stripe is energised by the correct signal input. Synchronisation is achieved by the insertion of beam position indicator stripes which produce a UV feedback signal via a detector to the multiplexing circuits to turn each colour on and off at the right time.

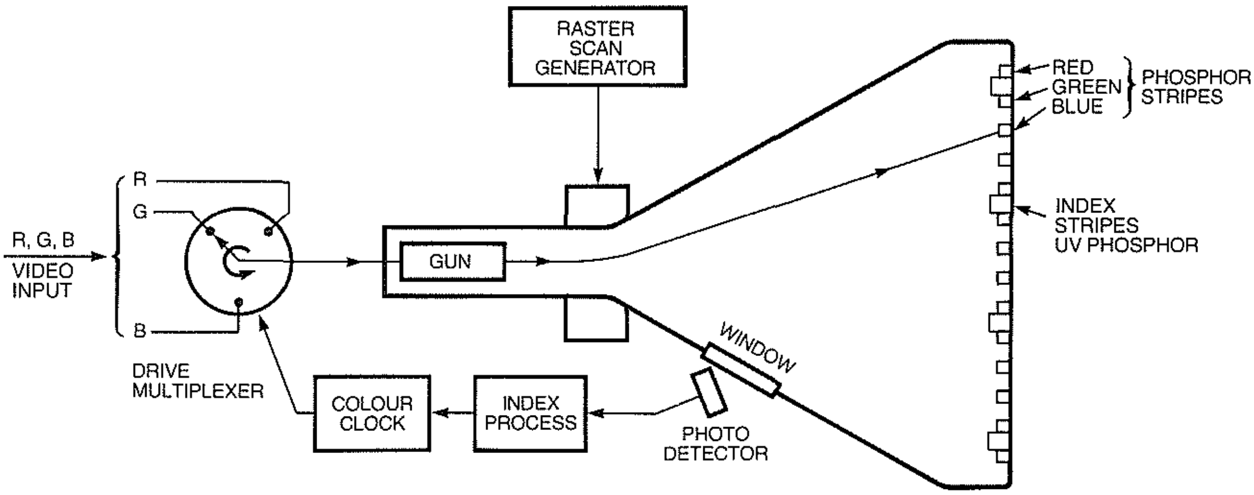



Fig. 9 Beam Index CRT Outline Scheme

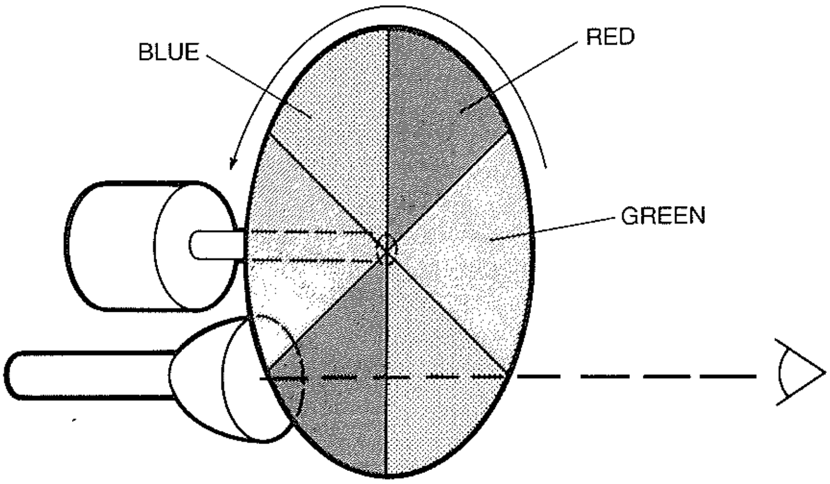
The biggest disadvantages of this method is that the electronics are complex and in order to keep complexity to a practical level it is only possible to use a video or raster mode keeping to one direction for the sweep of the beam. The advantages and disadvantages of the Beam Index are listed at Table 4.

| | |
|---|---|
| **Advantages** | Efficiency |
| | Simple CRT Construction |
| | Raster Capability |
| **Disadvantages** | Complex Electronics |
| | No Cursive Capability |

Table 4 Beam Index CRT Advantages and Disadvantages

Field Sequential Colour CRT

In the early days of commercial colour TV one of the contenders in the US was a sequential colour system. This technology used a 'black and white' CRT which projected through a spinning wheel having red, blue and green segments, Figure 10. The wheel was synchronised so that information of a particular colour was presented sequentially the refresh rate had to be trebled from 30 to 90 frames a second requiring an increase in bandwidth which was a problem at the time. The other obvious disadvantage was the space required to accommodate the spinning wheel.




**TIME SEQUENCED**

Fig. 10 Sequential Colour Addition

Recent work has been directed at using solid state colour switching filters to replace the spinning wheel. The advantages and disadvantages of the Field Sequential CRT are listed at Table 5.

**Advantages** High Resolution
High Brightness
Simple CRT Construction

**Disadvantages** Mechanical Spinning Wheel*
High Bandwidth Signal Required

***May be replaced by switched LCDs**

Table 5 Field Sequential CRT Advantages and Disadvantages

Channel Plate CRT

The channel plate or electron multiplier CRT[3] Figure 11 at present under development is an attempt to allow satisfactory display brightness and resolution to be attained in a much more compact unit than the other types. Deflection of the electrom beam is easier if the electron energy is low and to maintain a good spot size the current must also be low. To reduce the volume of a CRT the beam deflection angles must be increased and this calls for high switching voltages in electrostatic systems and high deflection currents in magnetic systems.

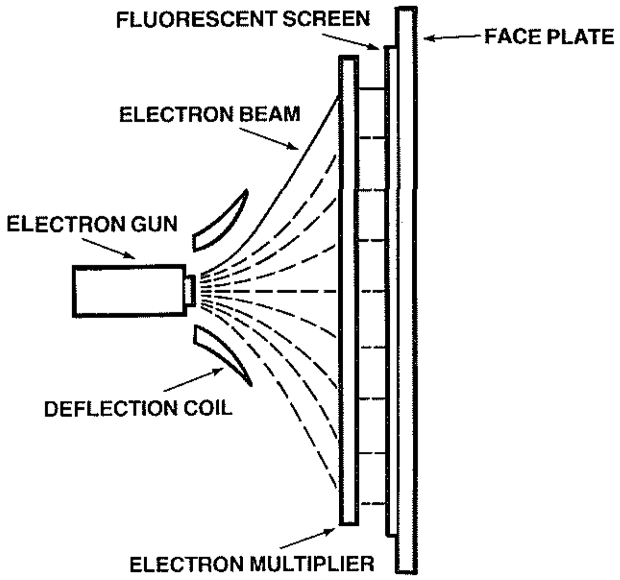



Fig. 11 A CRT Using an Electron Multiplier

The channel plate CRT has the scanning and light generation functions separated by an electron multiplier channel plate. Scanning is carried out with a low energy beam which is easily deflected. The current is subsequently amplified by the multiplier and the electrons accelerated before hitting the screen. Spot size is unaffected by increasing multiplier gain.

As well as a reduced volume CRT with a conventional beam path a flat deflection system using a folded beam path has also been demonstrated (see Figure 12). It is this device which if developed would offer a major reduction in weight and space required for the display. A display with a screen diagonal of 9 inches would be about 3 inches deep.

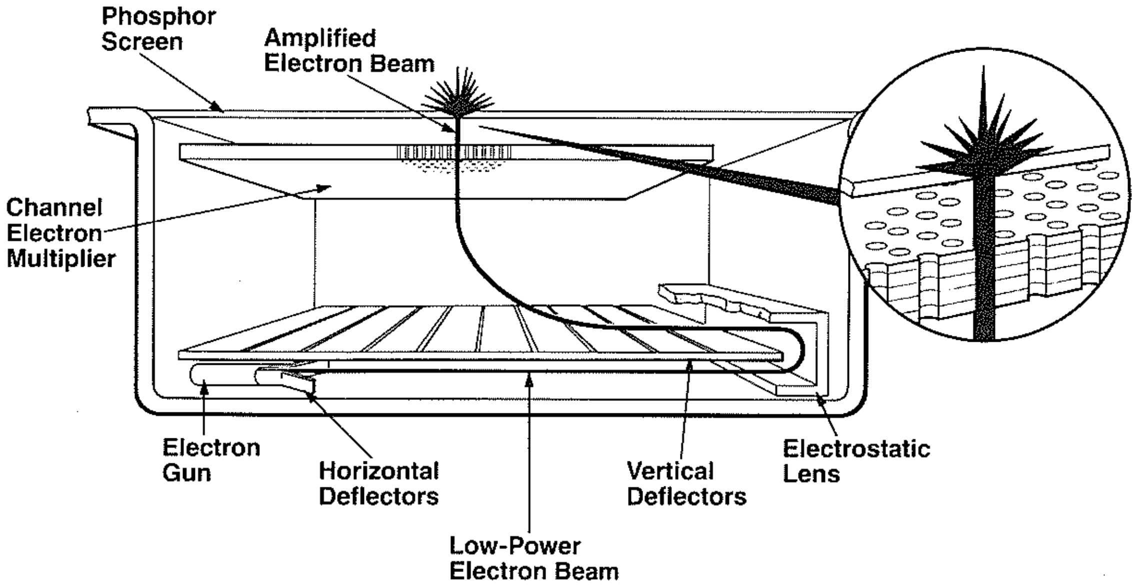



Fig. 12 Channel Electron Multiplier Folded-Gun CRT

Table 6 details advantages and disadvantages of the channel plate CRT.

| | |
|---|---|
| **Advantages** | Shallow Depth |
| | Reduced Weight |
| **Disadvantages** | Resolution Limited By Channel Plate |
| | Trapezoid Distortion Corrections Required |
| | Laboratory Equipment Status |

Table 6 Channel Plate F-CRT Advantages and Disadvantages

## Flat Panels

Flat panel technology offers the promise that the recognised disadvantages of CRTs may be overcome. If the question is asked whether anyone of the new technologies match or better the performance of the CRT as a true multifunction display today the answer is no. They all fail on at least one of the parametrs that are used to measure the performance of the CRT. The benefits to be obtained in aircraft application are savings in behind panel depth, weight, power, cooling and life cycle costs coupled with improved reliability and ease of retrofitting.

Out of the technologies available the three showing most promise for aircraft application are:

Liquid Crystal Displays (LCDs)
Thin Film Electroluminescent Displays (TFEL)
Light Emitting Diode (LEDs)

## Liquid Crystal Displays (LCDs)

Liquid Crystal Displays are non emissive devices using electro optic material to modulate light using one of several effects such as scattering and absorption. Figure 13 shows the structure of a twisted nematic liquid crystal cell. LCDs may either be reflective devices relying on ambient light or floodlighting illumination or they may be transparent requiring back projection of light. Power consumption is low. The brightness of the LCD display is a function of the brightness of the light source. Existing LC material cannot meet the full operating temperature range for military equipment without temperature control such as a heater.

Commercial developments have concentrated on numeric displays particularly in the watch and calculator market although graphic displays are also available. Low resolution monochrome LCD video displays are now being sold by the Japanese in miniature TV sets. Colour displays with back projection have also been developed. High resolution LCDs with pixel sizes of less than 0.3 mm have been demonstrated.

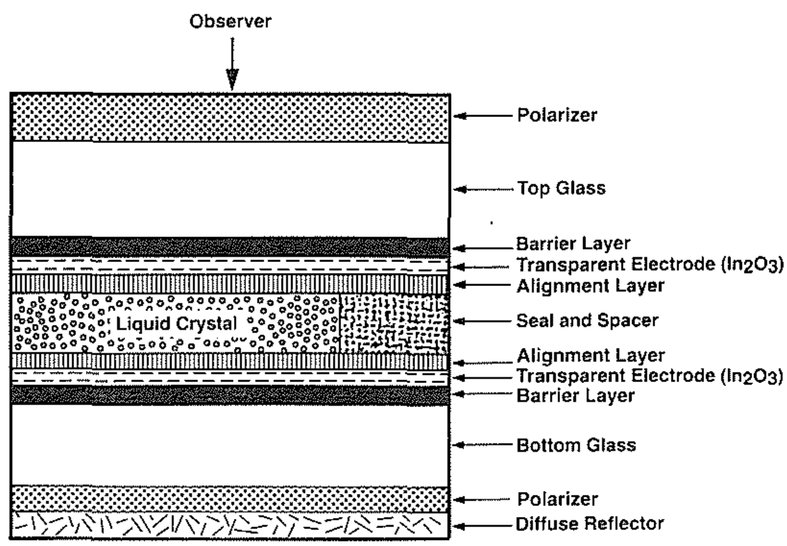



Fig. 13 Typical Structure of a Twisted Nematic Liquid Crystal Cell

Another method of obtaining good resolution colour video using LCDs is by adoption of switched layers in front of a CRT using the field sequential principle originally tried with the spinning wheel.

LCDs have obtained by far the largest share of commercial funding and seem to be favourite to win the race for large displays in the future.

Thin Film Electro Luminescent (TFEL)

AC driven thin film electroluminescent devices Figure 14 have a solid state thin film doped phosphor layer sandwiched between two dielectric insulating layers. A glass sheet having the transparent front electrodes deposited and patterned on it serves as the substrate for the TFEL layer. After depositing and patterning of the rear electrodes a second sheet of glass seals and completes the display. Except when activated the resulting display is transparent apart from the rear electrodes.

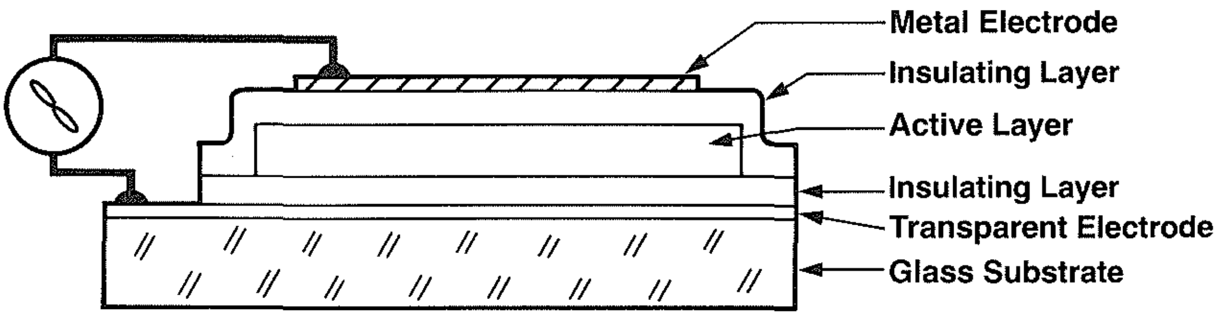



Fig. 14 Structure of an ACTFEL Device

By multiplexing hundreds of lines in a matrix with the crossed grid approach graphic and video displays have been demonstrated. The most common colour available is yellowish green. Research is proceeding to develop a purer green then red and blue materials. If that is achieved a triad or a three layer approach will allow full colour.

Light Emitting Diode (LEDs)

LEDs use an electroluminescent phenomenon in which electrons flow across a junction incorporating a compound which glows during current flow, Figure 15 Green, yellow, orange and red LEDs are available today. A lack of commercial interest in less efficient compounds has resulted in a less developed state for blue LEDs.

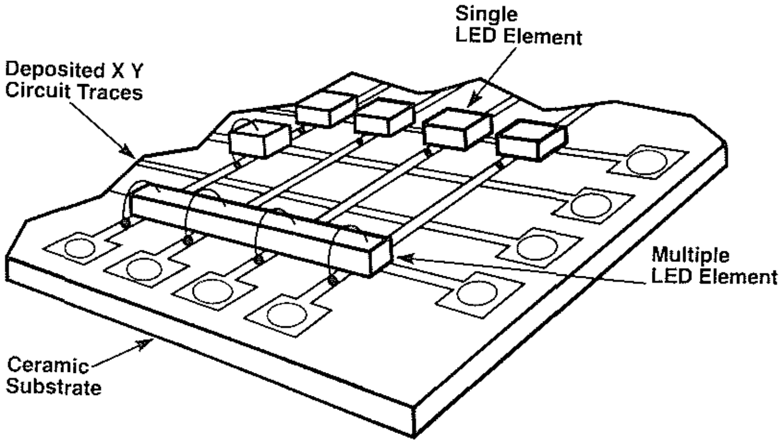



Fig. 15 LED Matrix Assembly

The primary thrust for LEDs for military use has been in green 64 pixel/inch arrays suitable for forming a mosaic of dot matrix modules. The modules may be fabricated by placement of single LEDs with their own electrical connection or by placement of monolithic LED array chips to form the standard 1 x 1 inch module. Each module is operated as an independently refreshed and updated display. Larger display areas up to 3 x 2 inches have been manufactured for alpha numeric displays in which blocks of LED elements have been laid down in rows on a single substrate.

Monochrome video presentations with 8 grey shades have also been demonstrated. Colour arrays in green, yellow and red are available but full colour awaits the development of blue LEDs.

Although power consumption is higher than for the other technologies and manufacturing costs are high LED matrix displays are ready for practical employment as limited capability multifunction displays where the high cost is offset by the benefits of reduced space and weight. Whether LED video displays are ever widely used is likely to depend on the advances or otherwise in the competing technologies.

Brightness and Contrast

Typical State of the Art luminance levels for CRTs and flat panel displays are shown at Table 7.

| CRT | RED | BLUE | GREEN |
|---|---|---|---|
| ● SHADOW MASK | 20-65 | 5-20 | 50-100 |
| ● PENETRATION | 20 | – | 100 |
| ● BEAM INDEX(estimated) | 50-100 | 25-50 | 150-200 |
| ● CHANNEL PLATE | ? | ? | ? |
| **FLAT PANEL** | | | |
| ● LCD | Depends on illumination source | | |
| ● LED | 50-100 | – | 50-100 |
| ● EL | 0-5 | 2 | 10 |

Table 7 Typical Brightness Levels (FL)

Summary

In order to satisfy the complex man machine interface requirements of future battlefield helicopters sensor data fusion display techniques will be necessary. Full colour displays capable of operation in raster, cursive and hybrid modes will provide the most flexible visual means of presenting such fused information. The shadow mask CRT is the only full colour multifunction display available at the moment which will satisfy aircraft requirements. Improvements in other CRT technologies are being made at the same time as advances in flat panel technology. Table 8 shows a prediction of when the various technologies could be applied to aircraft.

Once satisfactory flat panel technology is available cockpit designers will have a new freedom to exploit novel layouts. Even the totally enclosed cockpit concept with panoramic displays mooted as a means of providing protection against EMP, lasers and chemical weapons will not seem so far fetched.

| | VIDEO | GRAPHIC | ALPHA-NUMERIC |
|---|---|---|---|
| **CRT** | | | |
| • SHADOW MASK | 1986 | TODAY | TODAY |
| • PENETRATION | — | TODAY | TODAY |
| • BEAM INDEX | 1995 | 1995 | 1995 |
| • FIELD SEQUENTIAL | 2000 | 1995 | 1990 |
| • CHANNEL PLATE | ? | ? | ? |
| **FLAT PANEL** | | | |
| • LED | ? | 1986 | TODAY |
| • EL | ? | ? | ? |
| • LC | 1990 | 1990 | 1990 |

Table 8 Likely Date for Aircraft Application

REFERENCES


1) G.L. Cohill, et al., Integration of Sensor Fusion in Advanced Helicopter Cockpit Design. Paper presented at AGARD Guidance and Control conference May '84.

2) J.P. Rogers, et al., Impact of Advanced Technologty on Future Helicopter Preliminary Design. Paper presented at 20th European Rotorcraft Forum 1984.

3) A.W. Woodhead, The Channel Multiplier CRT. Paper given at NATO Workshop on Color Coded vs Monochrome Displays February '84.

4) J.H. Brindle, W.G. Mulley - The Pursuit of Color From a Display Technology Perspective. Paper given at NATO Workshop on Color Coded vs Monochrome Displays February '84.