

Panoramic Displays: The Next Generation of Fighter Aircraft Cockpits

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ABSTRACT

Since about 10 years the trend in aviation cockpit design is toward an increasing display area and a smaller number of individual displays at the same time. Modern display technology even allows building displays which are able to cover the area of the entire main instrument panel of a fighter cockpit. The application of large area displays offers the advantage to largely improve the situation of the pilot by augmenting his situation awareness, thus enhancing his operational capability. A display that provides a large display area (panoramic display) could not only be used to show a bigger amount of information but also to indicate this information in a more detailed manner at the same time and it also offers the chance to combine information thus supporting the generation of a mental model of the situation.

The introduction of a panoramic display in an aircraft cockpit, however, has to be initiated by conceptual work aiming to find the optimum way to both utilise the large display area and interact with the device. We therefore developed a display and control concept for the panoramic display and began to investigate the potential benefits of such a big screen. Our work comprises the evaluation of the pilot's situation awareness and workload in an operative simulation environment, considering his needs and situational impacts. In that context we explored potential ways to interact with such a display in order to identify the most promising control method(s).

The present report summarises our conceptual work on panoramic displays, the methodology we applied and the results of the usability study on interaction methods. It describes also our way ahead regarding the measurement of situation awareness. Further studies shall prove that panoramic displays can in fact contribute to improve the

performance of the entire system by supporting the pilot's process to build a proper mental model of the situation.

INTRODUCTION

Since the very beginnings of human aviation cockpit design is characterised by an ever growing amount of information and functions that have to be provided to the pilot, always reflecting the latest technological state of the art. Analog instruments were used for information presentation from the first days till the late 1960s and the number of analog dials was continuously increasing during that period due to new systems and equipment being introduced in the aircraft. Cockpits like that of the Concorde clearly show the limits of a design which is based solely on analog dials. In the early 70s multi-functional displays became available for use in aircraft cockpits. This new technology allowed indicating information items from multiple information sources on one display surface - aviation left the age of analog dials and entered the glass cockpit era.

The glass cockpits of modern fighter aircraft are a complex working environment. Thus modern cockpit design is associated to a great extent with automation of mainly basic aircraft aviation tasks, such as following a route or maintaining a certain altitude. These automation measures reduce the pilot's workload with regard to the flying task and allow him to concentrate on his tactical tasks. Therefore the pilots of modern fighter aircraft are rather an information manager than a fighter pilot of the old days. The continuous improvement of aircraft capabilities, e.g. sensor systems, is attended by huge amounts of available data and relevant information that have to be presented to the pilot in an ergonomic manner.

State-of-the-art aircraft like Eurofighter Typhoon, F-18 or Saab Gripen are usually equipped with three head down

displays that cover a total display area of 700 to 1000 cm². This cockpit configuration sets the limit for the presentation of information due to limited display area and separated display units. Today we face the same circumstances as cockpit designers and engineers in the 60s and 70s. An ever growing amount of information and functions still leads to the demand for an increased display area.

Already in the 1980s Eugene Adam identified the need for a display presenting the “big picture” in fighter aircraft cockpits in order to support the pilot's situation awareness and to reduce his mental workload. Unfortunately display technology at that time did not allow a realisation of the idea. At the beginning of the new millennium, however, cockpit designers, e.g. those of the F-35, took up the big picture concept since at that time display technology became increasingly mature to support large scale displays in aviation. These display technologies allow the integration of panoramic displays in fighter aircraft cockpits covering the whole instrument panel with a single and continuous display device.

So, just as 40 years ago, when the first glass cockpits evolved, we now have the opportunity to design a totally new generation of aircraft cockpits using panoramic displays. But before these cockpits are going into service a number of key issues need to be studied in order to make best use of the new technology. Two critical questions that need to be investigated before a big screen is integrated in a cockpit are:

1. Can a panoramic display be designed such that it provides the necessary interaction options for the pilot, considering that there is almost no space left for hardware buttons?
2. After having answered the first question it has to be clarified whether large area displays are able to improve the performance of the weapon system compared with the traditional cockpit layout.

In the following we present the latest status of the research project Panoramic Displays currently in progress at Cassidian Air Systems and we will illustrate our approach to answer the above questions. With regard to the first question we made a study investigating the usability of several methods to interact with the display in an operational context. The second question is currently being answered within the scope of a study which is largely related to situation awareness. The paper will also present the methodology of both investigations and the results of the usability study.

PANORAMIC DISPLAY: INITIAL DESIGN STEPS

Our initial activities with regard to large area displays in fighter aircraft cockpits concentrated on two critical aspects:

- How should the large display area be utilised to generate the maximum benefit for the pilot? This question is mainly related to information presentation aspects. Relevant findings are described below in the section *Display Concept*.

and

- What is the best way for the pilot to interact with such a big display? The control aspects relevant for panoramic displays are summarised in the section *Control Concept*.

DISPLAY CONCEPT

The panoramic display is located on the main instrument panel. Compared to a traditional layout consisting of 3 head down displays ([Figure 1](#)), the panoramic display offers more overall display space and a continuous display area ([Figure 2](#)). The geometrical shape of the novel display is based on the assumption that it is used to replace the HUD Control Panel and the three Multifunction Head Down Displays in the Eurofighter Cockpit. The large area information presentation results in three basic advantages:

- *Presentation of both a large map area and detailed map information at the same time*
- *Indication of three-dimensional perspective views (synthetic vision):* as an option to the conventional two-dimensional map view, a large scale three-dimensional perspective view can be presented to the pilot. A perspective view should rely on a high display resolution and a large area, particularly in the horizontal dimension, in order to generate a considerable operational benefit.
- *Presentation of additional information on the same display:* additional information can be displayed on the left and right region of the screen without masking the most important central display area. Hence different information groups, such as tactical or aircraft system information, can be indicated simultaneously, similar as on traditional displays.

Taking these advantages into account we developed a display concept which consists of two basic elements: the pilot awareness format and the side-window formats. The pilot awareness format is a full screen representation of the scene in either 2D or perspective view. The side-window formats are selectable; they offer additional information, according to the pilot's needs.



Figure 1. Traditional Cockpit Configuration with three Head Down Displays



Figure 2. Cockpit Configuration with the Panoramic Display

Pilot Awareness Format

As the content of the pilot awareness (PA) format is vital to update the pilot's picture of the scene, it is displayed permanently and independently of the selection of a side-window format. The PA format covers the whole screen area; side-window formats are displayed on top of the PA format. The PA format includes two presentation variants of the surrounding area: a conventional two dimensional map and alternatively a three dimensional perspective view. The transition from one view to the other can be explained by means of the “cube metaphor” (Figure 3): a virtual camera can be positioned such that a continuous transition from a map view to an exocentric horizontal view can be implemented. The perspective view includes all spatial

dimensions of the scene including geographical, topographical, navigational and tactical information. Relevant information is traceable during the transition which supports the pilot's mental model of the situation. Thus it provides the pilot with an integrated picture which in traditional cockpits has to be generated mentally by integrating different views (plan view, side view). We assume that this design supports the pilot's information processing by enhancing his situation awareness. The necessary evidence shall be provided by means of an appropriate study (see section *Assessment of Situation Awareness* below).

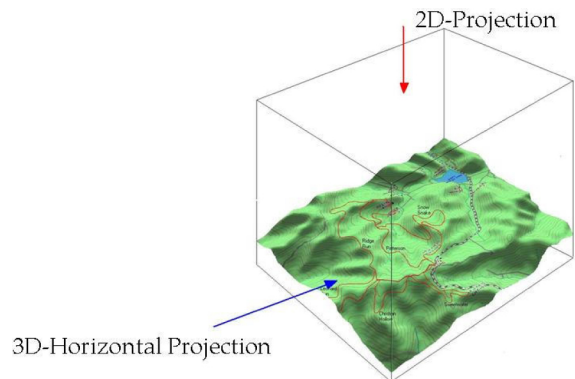


Figure 3. Visualisation of the “Cube Metaphor”

Side-Window Formats

Information that needs not to be displayed permanently is provided by means of side-window formats. Kellerer (2010) defined those formats as a specified set of information and its graphical representation on the panoramic display. The display configuration shown in figure 2 is able to display up to four side-window formats at the same time. All formats can be selected individually according to the pilot's demands. There are four defined positions: an upper and a lower position for both the left and right hand side-window. The concept comprises fixed positions of the windows in order to prevent a completely flexible arrangement on the screen which only utilises the pilot's cognitive resources. Formats can alternatively be arranged such that they take the whole display height.

CONTROL CONCEPT

The control concept needs to be consistent with the display concept so that they form a consistent entity. In the interest of a maximised display area, conventional hardware buttons shall be excluded. This decision restricts the number of suitable basic interaction methods to two: voice control and cursor control. Due to the unsatisfactory reliability of voice control, particularly in the fighter context, and its comparably low operator acceptance, this technique is inappropriate as primary control method. So cursor control is left as the only adequate option. Boff (1983) distinguishes two sorts of cursor

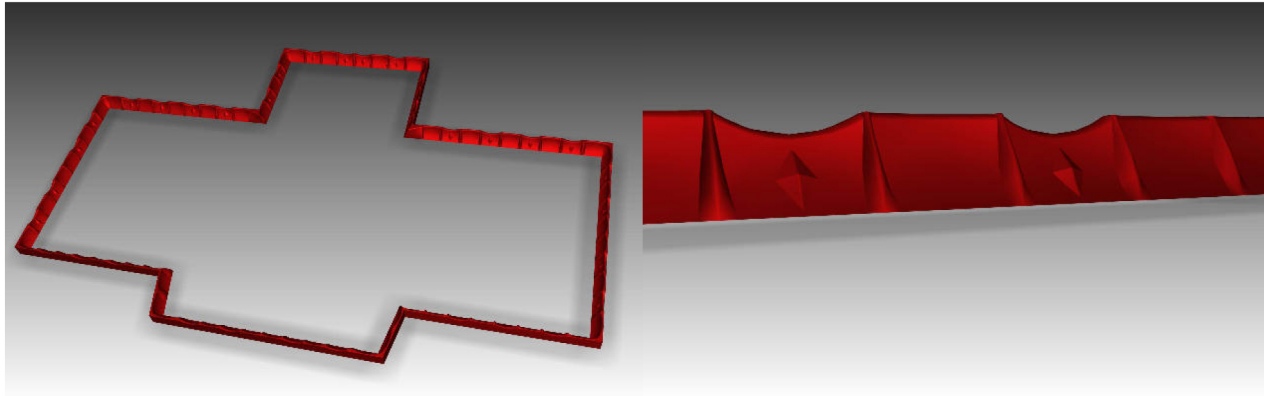


Figure 4. Haptic Display Frame

control devices: direct (e.g. touch screen, light pen) and indirect input elements (e.g. mouse, trackball, joystick). Our final control concept is based on both kinds of cursor control, direct and indirect input elements. The redundancy is not only essential from a technical point of view, but also from an operational perspective. For situations where the pilot cannot take his hands away from the flight controls indirect cursor control must be provided by a cursor control device on the throttle grip. For the control concept redundancy of control devices means that the interaction must be designed in a consistent manner in order not to confuse the pilot.

Direct input elements are characterised by intuitive usability and require adequate hand eye coordination of the user (Kerschenlohr, 2007). Their most noticeable disadvantage is the limited accuracy in cursor positioning tasks. Indirect cursor control devices, although not as intuitively usable as direct input elements, have advantages with regard to user fatigue and most users are familiar with their utilisation. In addition, indirect control devices can be optimised for the operational context by adaptation of the ratio of displacement of the control unit and the cursor. Further detail on the comparison of direct and indirect cursor control devices can be found in the section *Usability of Control Devices*.

A proper control concept must make sure that all functions of the conventional displays that have been replaced by the panoramic display can be performed with the touch screen. Furthermore, the display concept makes the following demands on the control concept:

- the content of the in side-window display formats must be controllable in a way comparable with the conventional displays interaction and
- it must be possible to also interact with mobile/moving information elements on the PA format.

We differentiate between basic controls for fixed positions and distributed controls for mobile and moving elements. Their details are explained below.

Basic Controls

Basic controls are graphical elements, whose position on the screen are fixed, either at the screen edge or inside a display format (e.g. stores position). Examples of those control elements are in particular virtual buttons. Contrary to hard buttons virtual buttons are displayed situation dependent. As virtual buttons are only graphical representations on the screen, distinguishing different buttons by the means of their shape is not possible.

Basis controls are primarily used to modify whole views, for instance side-window configurations, the contents of single side-window formats or display parameters of the pilot awareness format. We decided to place basic controls preferably at the corners and edges of the display in order to keep the display area maximised and to allow the pilot to rest and stabilise his hand on the display frame. The frame itself should be designed such that the finger of the operator is guided towards the virtual button position and that there is a certain possibility to haptically distinguish between adjacent positions (Figure 4).

Designing basic controls as menu or multifunction buttons (see figure 5) leads to a tidy and clearly arranged display layout. The fact that three input steps are acceptable from an operational point of view (Kerschenlohr, 2007) allows reducing the maximum number of buttons displayed at any one time. This moding is clarified in figure 5, showing the format selection process. In addition, the design provides the option to individually define basic settings (via the PRE button) which permit a quick selection of the preferred side-window configuration, reducing the number of selection steps to only two.

Distributed Controls

The most natural way to interact with mobile or moving objects such as waypoints or tracks on the screen is direct access. That is the relevant object has already to be a control element, the activation of which opens either additional