THE DESIGN AND IMPLEMENTATION OF CRT DISPLAYS IN THE TCV REAL-TIME SIMULATION

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INTRODUCTION

NASA's Terminal Configured Vehicle (TCV) program is an advanced technology development activity focused on conventional transport aircraft that will operate routinely in reduced weather minima in future high-density terminal areas equipped with new landing systems, navigational aids, and increased air traffic control automation. The broad objectives of the program are to evaluate new concepts in airborne systems (avionics and air vehicle) and operational flight procedures for reducing weather minima, increasing air traffic controller productivity and airport and airway capacity, saving fuel, and reducing noise by more efficient terminal techniques.

A Boeing 737-100 series aircraft was procured with a second flight deck and several computers installed in the passenger cabin. The aircraft is designed to be normally flown from the forward flight deck using the primary control systems and from the second (aft) flight deck using digital fly-by-wire control techniques. The aircraft can be flown under simulated category III conditions (zero visibility, zero ceiling) safely through the monitoring and take over capabilities of the forward flight deck crew. Included in the aircraft are two sets of computer driven CRT displays configured as the primary flight instrumentation indicating vertical and horizontal situation.

THE TCV SIMULATION

One of the elements in support of the TCV program is a sophisticated simulation system. The simulation has been developed to duplicate the operation of the aft flight deck in the 737 aircraft. A nearly identical cab was purchased from Boeing as part of the simulation system. The simulator facility can be used to develop and evaluate concepts of advanced flight procedures, provide pilot familiarization with advanced piloting techniques and provide a mechanism through which interested parties can see and evaluate research activities.

The simulation facility consists of an aft flight deck simulator, shown in figure 1, a CDC 6600 real-time simulation system, and an Adage Graphics Terminal. The simulator is equipped with realistic flight instrumentation including basic cockpit instruments, Automatic Guidance and Control panel (AGCS), Navigation Control and Display Unit (NCDU), Electronic Attitude and Direction Indicator (EADI), Electronic Horizontal Situation Indicator (EHSI), and panel mounted controllers, as shown in figure 2.

The simulation software includes the basic 737 nonlinear real-time simulation with the additions of landing gear dynamics, gust and wind models, nonlinear actuator models, and ILS and MLS (Instrument Landing System and Microwave Landing System) ground systems. Automatic flight control and navigation control functions have also been simulated and include control wheel steering, autoland with decrab and rollout capability, and navigation guidance and control. Bulk data storage for geographic map data, display computations, and NCDU computations on the CDC 6600 combined with the display generation capability of the Adage Graphics Terminal will present to the simulator pilot displays similar to those used on the aircraft with equivalent man-machine interaction capabilities. The two displays form the primary flight instrumentation for the pilot. The displays are dynamic images depicting critical flight information thus providing the pilot with a view of the flight situation.

The display equipment in the aircraft was tailored specifically for the TCV program and utilizes both raster and stroke drawing techniques. Although powerful, the hardwired and microprogrammed nature of the equipment makes it less flexible than desired for use in a laboratory environment. To provide the flexibility needed for the research program, an Adage system was chosen to generate the simulation displays. The Adage machine is very flexible from a programming standpoint and permits research in display formats to be realistically interwoven into the research schedule.

The Adage Graphics Terminal is a high speed interactive refresh-type graphics system. As configured at NASA Langley, it has 32K of core memory, a 30-bit CPU and four independently addressable CRT units. Hardware is provided to effect coordinate transformations. The Adage system is a completely self contained computer system with a powerful disk operating system, text editor and FORTRAN compiler. To support the cockpit displays, two remote CRT units were wired in parallel with two of the Adage scopes. In addition, three video scan conversion units are attached to the system, providing the capability for image transmission through NASA's extensive video distribution network.

THE EADI DISPLAY

The EADI display, shown in figure 3, is the most primary display for the pilot. The EADI is a head-down type display for attitude, vertical situation, flight director commands and control information. The data presented can vary under control of the EADI mode control panel, depicted in figure 4. The EADI contains a number of dynamic elements which are updated at the rate of 16 times a second. The entire image is refreshed at 40 times a second. The EADI has a viewable area of 17.8 cm by 14.0 cm (7 inches by 5.5 inches). The EADI provides the pilot with information useful in vertical and horizontal flight maneuvers. For example, in a typical landing situation, the following information can be presented on the display:

1. pitch and bank angle information
2. altitude
3. deviation from ILS beam
4. a true perspective runway image
5. flight path and flight path acceleration
6. deviation from required heading.

The structure of the EADI display is defined for the most part by the Adage program and is modified dynamically by displacement and rotation values derived from data sent by the main simulation routines in the CDC 6600. A special case is the perspective runway, which is transmitted as an actual image list suitable for display without further processing.

THE EHSI DISPLAY

The EHSI, shown in figure 5, is designed to provide the pilot with sufficient information for him to perform all horizontal and time-controlled flight maneuvers. The display replaces the electromechanical Horizontal Situation Indicator (HSI). It depicts that portion of the horizontal navigation and guidance information that lends itself to graphic representation and is of enough importance to warrant primary panel space. The EHSI has a viewable area 17.8 cm by 14.0 cm (7 inches by 5.5 inches). Data presented on the display are processed digitally in the CDC 6600 and the Adage. The display is updated 16 times a second. Image refresh is at 40 frames a second. These rates are sufficient for smooth dynamic flow at rates typically encountered in flight maneuvers. The image is controlled by the EHSI mode control panel shown in figure 6. The salient features depicted on the EHSI include:

1. aircraft horizontal position relative to a map showing flight path, airports, navaids, waypoints, boundary lines, and other points of interest
2. a curved trend indicator showing an extrapolated aircraft position 30, 60 and 90 seconds ahead
3. digital readouts for magnetic heading and ground speed
4. textual information indicating aircraft guidance mode and map scale
5. time guidance indicators.

DISPLAY IMPLEMENTATION

The basic simulation equations of motion and control systems are designed for an iteration rate of 32 times a second as provided by NASA's CDC real-time computer systems. The I/O structure of the CDC 6600 and the real-time operating system support bi-directional data transfers once every frame (each frame is 1/32 of a second long). Due to the heavy I/O requirements of the simulation routines and the necessity to maintain this fixed frame rate, the time made available for 6600 to Adage transfers allows only 1200 bits to be transmitted each frame. The amount of data required to support the Adage displays far exceeds this number. A mechanism for accumulating display data and transmitting it in small blocks was developed. Fortunately, the displays need not be fully synchronized with the control programs since small delays and inaccuracies are not discernable at a visual level by the pilot.

The data required by the Adage are logically divided into two major categories: real-time data and background data. The real-time data is characterized by the rate at which it is processed by the Adage display routines to maintain an illusion of continuous motion. The background image data are more static, being calculated over a period of several seconds.

To handle the influx of varied data, an interface package has been developed that provides the flexibility required. On the Adage, several double buffered input areas are defined to accommodate the transmitted blocks of each category. Each 1200 bit transmission may contain several data blocks of variable length headed by a type and length indicator. As data are generated and transmitted to the Adage, a "swap" code may be inserted to indicate that the data of a particular type has been fully transmitted. This causes the completed buffer load to be made available to the Adage display routines.

In this fashion, an asynchronous buffering technique was implemented that frees the CDC programmer from the fixed frame rate and fixed data length output restrictions imposed by the system. In addition, the ability to tag outgoing data as being destined for a particular buffer permits the CDC programmer to send actual image lists, if low update rates are permitted, or values to be applied dynamically to images already in Adage memory. Included as part of the simulation software are generalized Adage image support subroutines providing the CDC programmer with the capability to display fairly static images without becoming conversant with a complex stand-alone graphics system. These routines provide for data conversion, 2D and 3D clipping and perspective, and the generation of Adage format image lists. However, if the full power of the Adage is to be fully utilized, transmission of dynamic image modifying values and an appropriate Adage program are required. In the case of the TCV simulation, a hybrid approach was taken. Rapidly transmitted small blocks of data were used to modify the EADI and EHSI dynamic displays, while the map vector and character data were accumulated slowly.

The key advantage to this approach is that it permits the simulation programmer to exploit the capabilities of each computer system to the fullest extent. In the case of the TCV simulation, it permitted the simultaneous display of two complex images using a single graphics system. Additionally, this approach enabled programmers with a minimum of graphics experience to program a relatively large part of the display processing task.

CONCLUSION

In many computing environments, the use of computer graphics is becoming increasingly attractive. Despite advances in hardware and software, graphic techniques remain somewhat mysterious to many programmers. In developing this simulation, we have devised methods to multiply the benefits of using a mini-computer based, stand-alone graphics system with a properly designed interface to a large simulation computer. Primarily, the division of computational load based on the abilities of the respective machines can be effected. These methods minimize the training requirements of simulation programmers wishing to use dynamic graphics. From a personnel standpoint, having a distinct dichotomy between the two worlds of graphics and simulation, in conjunction with a interface package similiar to the one described, permits a small number of graphics oriented people to support a large simulation community. A system such as the Adage can provide a great deal of power and flexibility not only for dedicated simulation uses, but for engineering applications in general. The techniques used in the successful integration of a variety of systems in support of the EADI and EHSI displays helped make the TCV simulation a useful and practical research tool.

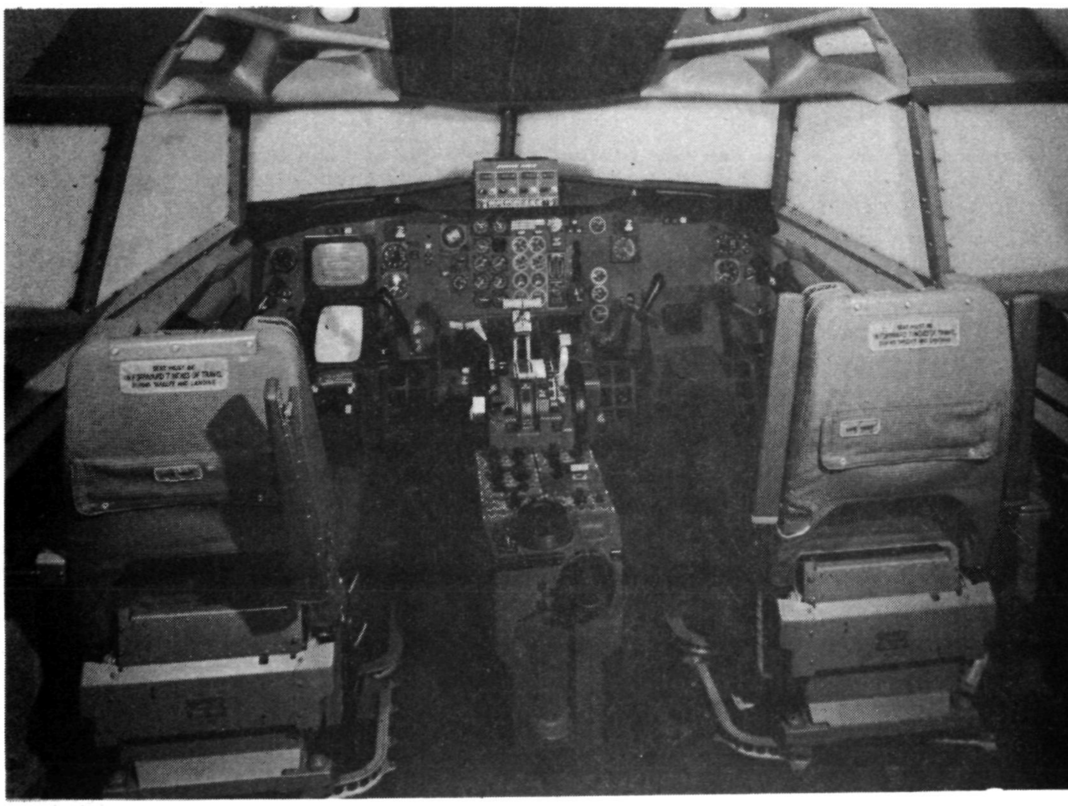

Figure 1 - Aft Flight Deck

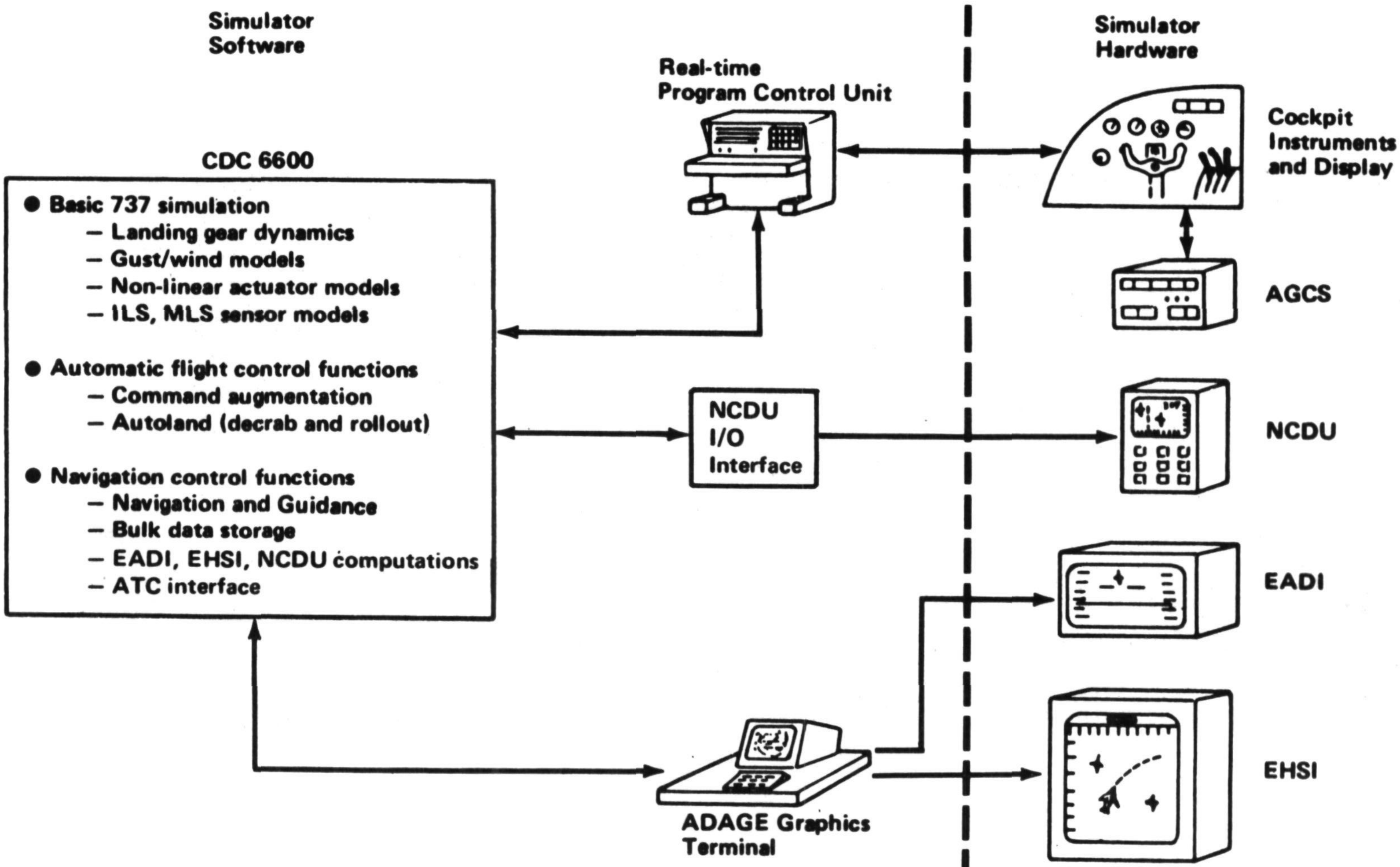

Figure 2 - Simulation System Block Diagram

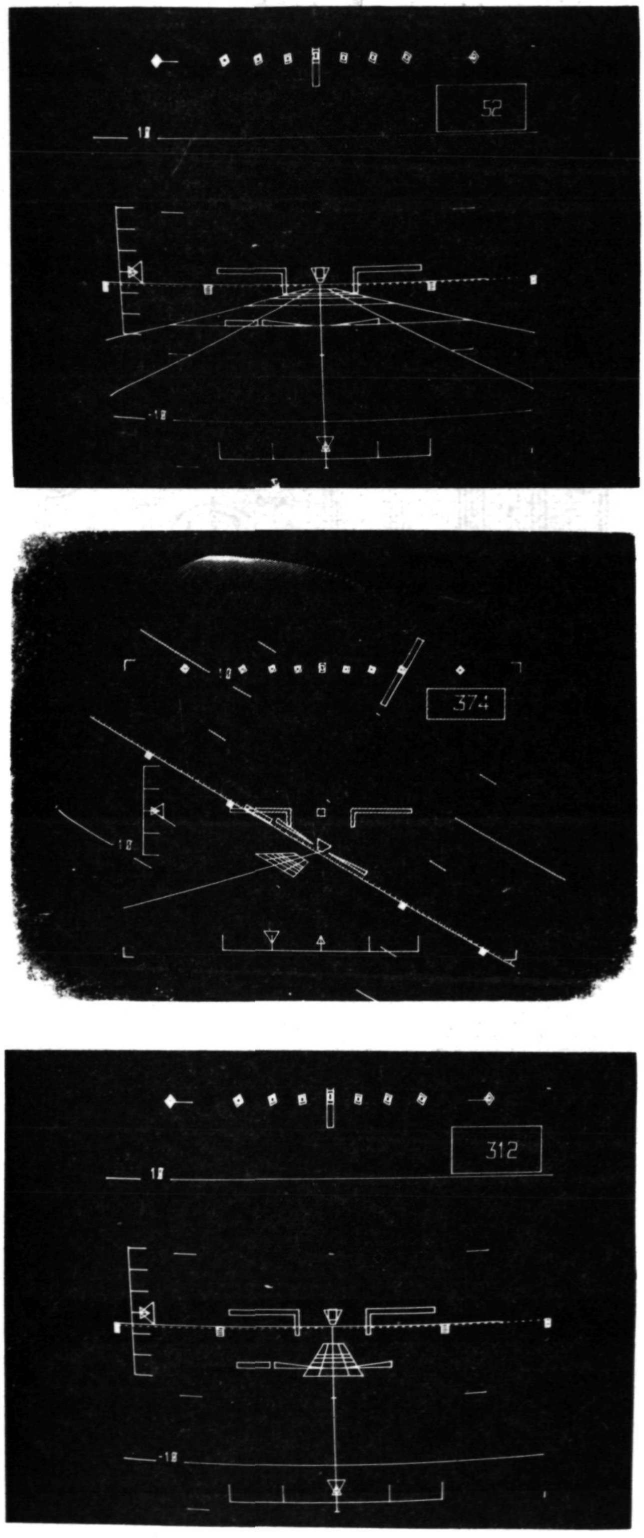

Figure 3 - EADI Displays

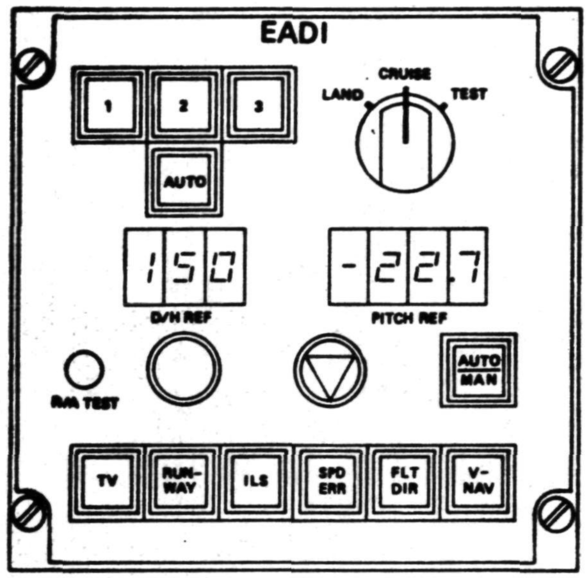

Figure 4 - EADI Mode Control Panel

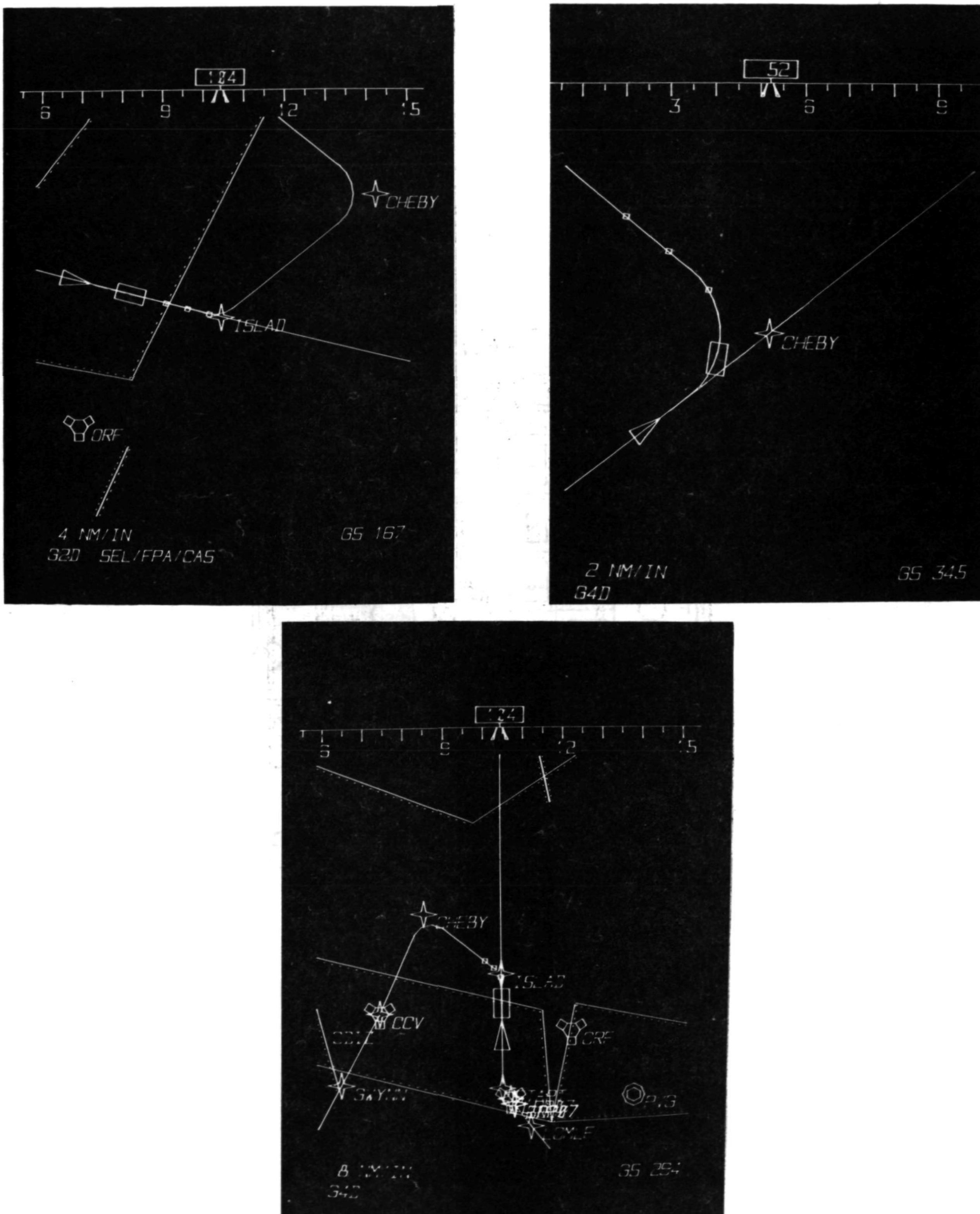

Figure 5 - EHSI Displays

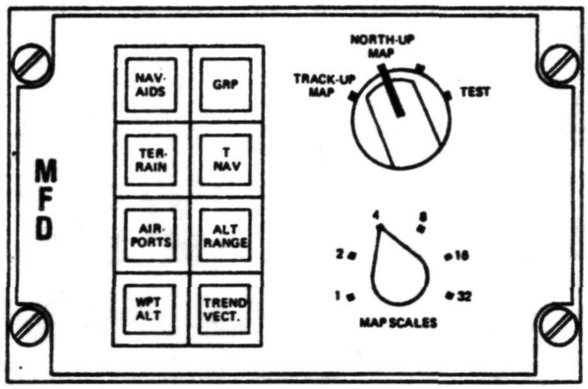

Figure 6 - EHSI Mode Control Panel