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Description of the Primary Flight Display and Flight Guidance System Logic in the NASA B-737 Transport Systems Research Vehicle

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SUMMARY

A primary flight display format on an 8" x 8" CRT has been developed in 1990 for the NASA Transport Systems Research Vehicle B-737-100 airplane. This primary display format has been integrated with the flight guidance and control system logic in support of various flight tests conducted with the airplane. This report describes the functional operation of the flight guidance mode control panel and the corresponding primary flight display formats.

INTRODUCTION

The Advanced Transport Operating Systems Program of the National Aeronautics and Space Administration is a research activity focused on the development of advanced operating systems technology necessary for conventional transport aircraft to operate routinely in reduced weather minima in a future high-density terminal area. Flight experiments are conducted in this program in the Transport Systems Research Vehicle (TSRV) which is a modified Boeing 737-100 airplane shown in figure 1.

The airplane is equipped with highly flexible experimental systems consisting of a flight display system, a digital fly-by-wire flight control and flight guidance system, and an advanced area navigation system. These experimental systems have been overlayed on the conventional airplane navigation and flight control systems. This allows a wide variety of flight test experiments to be implemented quickly for test purposes while still retaining the operational safety of the conventional airplane flight systems.

A research flight deck (RFD) is located in the cabin behind the conventional flight deck as shown in figure 2. Total flight operations from take off, en route, to landings may be performed within the RFD. The RFD is a full-size cockpit that contains eight 8" x 8" sized, flight quality, color CRT displays as shown in figure 3. Each pilot has a primary flight display (PFD), a map display, and a control display unit (CDU) to interface with the flight management system (FMS).

The display formats on each of the research flight crew members PFD were designed to support flight tests in the TSRV airplane beginning in 1990. These display formats are integrated in design to correspond to the selected flight control mode (autopilot, velocity vector control wheel steering, or attitude control wheel steering) and the selected flight guidance. Flight guidance and flight control system modes may be selected by the research pilots through

the mode control panel located in the center of the glare shield.

This report describes the operational functions of the flight control system mode control panel logic and the corresponding display formats on the PFD.

ABBREVIATIONS

ACWS	Attitude control wheel steering
AUTO	Autopilot flight control mode
ALT	Altitude hold guidance mode-ALT ENG label on the MCP
CAS	Calibrated airspeed hold autothrottle mode-CAS ENG label on the MCP
FMS	Flight management system
FPA	Flight path angle guidance mode-FPA SEL label on the MCP
HOR PATH	Horizontal path guidance mode
ILS GS	Instrument landing system glide slope
ILS LOC	Instrument landing system localizer
LAND	Land arm and engaged guidance mode
MCP	Flight control system mode control panel
MLS AZ	Microwave landing system azimuth
MLS GP	Microwave landing system glide path
PFD	Primary flight display
RFD	Research flight deck
TKA	Track angle hold guidance mode-TKA SEL label on the MCP
TIME PATH	Time control (ground speed) autothrottle mode
TSRV	Transport Systems Research Vehicle
VERT PATH	Vertical path guidance mode
VCWS	Velocity vector control wheel steering

DEFINITIONS

Guidance--Commands computed by the flight management system used for inputs to the primary flight display and the map display and used to drive the flight director and/or the flight control system.

Situation information--Performance information used by the flight management system to compute commands. This information is also used to drive symbology in the flight displays. Examples of situation information include lateral and vertical path tracking errors, airspeed error, current track angle, altitude, and airspeed.

OPERATIONAL DESCRIPTION OF THE FLIGHT CONTROL SYSTEM AND ITS MODE CONTROL PANEL

Flight Control System

The Transport Systems Research Vehicle (TSRV) airplane has a digital electronic flight control system. This system may be operated in an automatic flight mode or manually flown in either an attitude control wheel steering mode or a velocity vector control wheel steering mode. The manually controlled flight will be made with a fly-by-wire side stick controller handle.

In the automatic mode, guidance must be provided to the autopilot in both the lateral and vertical axes. This guidance will be provided by the pilot through selection of the desired guidance modes on the flight control system mode control panel (MCP) located on the center of the glare shield in the RFD.

The MCP and the PFD are integrated such that all selected guidance modes, mode status (active, armed, or off), and associated guidance/situation information are shown on both the MCP and the PFD.

Autopilot Modes

The research flight deck can be operated from three different autopilot modes; automatic (AUTO), velocity vector control wheel steering (VCWS), and attitude control wheel steering (ACWS). These modes are selectable by the flight crew by pushing the appropriate button on the MCP.

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AUTO Mode--The AUTO mode in the flight control system controls the airplane for hands-off flight. The AUTO mode requires guidance modes to be selected in both the lateral and vertical axes of the airplane. If the flight crew selects the AUTO mode without selecting both lateral and vertical guidance modes, the default guidance modes of track angle hold (TKA) and/or flight path angle hold (FPA) will be used. If the flight crew had previously selected lateral and vertical guidance modes, they will be used by the AUTO mode.

When operating in the AUTO mode, the flight crew may change the lateral and vertical guidance modes as they choose. However, if either the lateral and/or the vertical guidance modes are deleted, the AUTO mode will be demoded to VCWS and the flight crew will have to hand-fly the airplane.

VCWS Mode--The VCWS mode in the flight control system controls the airplane from inputs by the pilot through the fly-by-wire side stick controller. The VCWS has two sub-modes of operation in both the lateral and the vertical axes.

In the lateral axis of the VCWS, when operating near wings-level (bank angle approximately zero), a track angle sub-mode will be used to control the airplane laterally. In this sub-mode, the flight control system will maintain the current commanded track angle (present track angle of the airplane) of the airplane and drive the bank angle to zero. When operating in the track-angle sub-mode, a crows foot symbol, indicating the direction of the track angle, will be shown on the PFD at the center of the horizon line.

The commanded track angle may have small adjustments made to it (and corresponding movement of the crows foot) through a trim button on top of the side-stick controller handle. When fine adjustments are made through the trim button, the crows foot will remain on the PFD. When adjustments to the commanded track angle are made by banking the airplane with the side-stick controller, the crows foot will be removed until the bank angle is brought back to approximately wings level.

The second lateral axis sub-mode of the VCWS is the bank angle hold sub-mode. This sub-mode is active when the airplane is being banked by the flight crew. When the pilot releases the side stick controller while the airplane is in a bank angle other than wings level, the flight control system will maintain that bank angle.

If a bank angle between 30 and 45 degrees is established by the pilot, he must continue to make an input through the side stick control handle to maintain that bank angle. If the pilot releases the side stick controller when the bank angle of the airplane is greater than 30 degrees, the flight control system will return the airplane to a 30 degree bank

angle and maintain that bank until further inputs are made by the pilot. The maximum bank angle of the airplane that can be made through the side-stick controller is 45 degrees.

In the vertical axis of the VCWS, when operating with the flight path angle nearly level, an altitude hold sub-mode will be used to control the airplane. In this sub-mode, the flight control system will maintain the current altitude of the airplane. When operating in this altitude hold sub-mode, the diamond symbol in the center of the flight path angle wedges on the PFD will be filled with an opaque white color. This white fill is removed from the diamond when the crew makes inputs through the side stick controller to change the flight path angle of the airplane.

The second vertical axis sub-mode of the VCWS is the flight path angle hold sub-mode. This sub-mode is active when the airplane has been commanded to fly any flight path angle not at level flight. When in the flight path angle hold sub-mode, the white fill is removed from the diamond between the flight path angle wedges on the PFD.

ACWS Mode--The ACWS mode in the flight control system controls the airplane from inputs by the pilot through the fly-by-wire side stick controller. In the lateral axis, the ACWS mode maintains the bank angle of the airplane. When the bank angle of the airplane is approximately wings level and no inputs are made through the side-stick controller, the flight control system will level the wings. In the vertical axis, the ACWS mode maintains the pitch attitude of the airplane.

Autothrottle Modes

The research flight deck can be operated in either a manual throttle mode (including reverse thrust) or in two different autothrottle modes. These autothrottle modes are CAS (calibrated airspeed engage) and TIME PATH (4D path--a 3 dimensional path with time and speed assignments for each waypoint).

CAS--The CAS mode controls the throttles to maintain the airspeed selected on the MCP. This speed will also be shown on the PFD numerically and via an airspeed bug symbol adjacent to the desired airspeed on the airspeed scale. The throttles will not exceed the maximum power settings computed by the flight management system.

TIME PATH--The TIME PATH mode controls the throttles to maintain a ground speed computed by the flight management system. The commanded ground speed is a function of ground speeds and times assigned to each waypoint by the flight crew

through the FMS CDU and the current time error while the airplane is being flown along the path.

MODE CONTROL PANEL LAYOUT AND OPERATIONS

Figure 4 shows the layout of the flight control system mode control panel. Pilot selection of the flight control modes, the autothrottle modes, and the guidance modes are made through this panel by pushing the back-lighted mode select buttons.

Settings for the CAS autothrottle mode and for the ALT, FPA, and TKA guidance modes may be made by turning the knobs next to the mode select buttons. The numerical value for these settings are shown on the windows adjacent to the selection buttons and knobs. When these autothrottle and guidance modes are not in an active or armed status, the windows will display the current state (i.e., airspeed, altitude, flight path angle, and/or track angle) of the airplane.

Figure 5 shows the general functional layout of the MCP. The autopilot mode selections are made from the area in the lower left-hand corner of the MCP. The autothrottles are selected from the upper left-hand area and from the lower right-hand side. The remaining area contains guidance mode selections.

The back-lighted select buttons can have up to four different light combinations.

Light-off--Mode is turned off. No guidance or display information for this mode is shown. The number shown in the window (CAS, ALT, FPA, and TKA modes) is the current state of the airplane.

Blue light--Mode is turned off, however, guidance may be shown on the PFD display in a blue color. The number shown in the window (CAS, ALT, FPA, and TKA modes) is the pilot-selected value. If the mode was not selected by pressing the mode button, the blue light and guidance information on the PFD will be removed in 8 seconds.

Amber light--Mode is in the armed status for capture. Guidance information will be shown on the PFD in an amber color when in an armed status. When the mode capture criteria are satisfied, the mode will be changed to an active status.

Green light--Mode is in the active status. Guidance information will be shown on the PFD in a green color. This guidance will be driving the flight control system when in the AUTO mode.

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All possible combinations of lights for each mode on the MCP are shown in figure 6.

Operation of the MCP is based on the following rules. Exceptions to these rules are limited, but will be noted where they occur.

1)   In the lateral axis (TKA, HOR PATH, ILS LOC or MLS AZ from the LAND mode) and in the vertical axis (FPA, ALT, VERT PATH, ILS GS or MLS GP from the LAND mode), there can only be one or two modes simultaneously selected and, only one mode can be in an active status (green) and only one can be in an armed status (amber) at the same time.

2)   The modes in the active status (green) provide all inputs to the autopilot, flight director (flight director is not available at this time), and situation information shown on the PFD.

3)   When the capture criteria of the mode in the armed status (amber) are satisfied, that mode will become active (green) and replace the previous active mode.

4)   If a new mode has been selected by the pilot and it passes all of its capture criteria, it will replace both the current armed (amber) and active (green) status modes.

5)   If a new mode has been selected by the pilot and it passes only its armed status criteria, it will replace the current armed (amber) status mode.

6)   If a new mode has been selected by the pilot and it passes only the armed status criteria, it will require a second mode to be active that ensures capture of the originally selected mode. In this case, both of these modes will replace the current armed (amber) status mode and the current active (green) status mode. (Example--ALT will be in an armed status and require a captured status FPA when ALT was selected by the pilot and the airplane was more than 1200 feet from the desired altitude.)

7)   Pilot-select (blue light and blue situation information on the PFD) comes on when the appropriate MCP knob is turned by the pilot when the mode was in the light-off status. The blue light also comes on the HOR PATH, VERT PATH, and TIME PATH if the paths were not defined in the FMS when these select buttons are pushed.

8)   Pilot-select (blue light and blue situation display) automatically returns to light-off status 8 seconds after the last knob twist if the pilot does not manually remove or change to armed/active status. When the light-off status occurs, the blue light on the mode select button and the associated blue guidance on the PFD will be removed.

9)   Knob twists while a mode is in the armed or active status will result in the mode remaining in that status unless other criteria specifies changes.

10)   Pressing a mode button with a green light status will cause that mode to be changed to a light-off status (i.e., that mode is shut off) (Note the exception that the CAS mode select button and the corresponding guidance on the PFD turns amber if the green CAS button is pushed.)

This will also result in any amber (armed) mode in the same axis to be changed to a light-off status. (Note the exceptions that ILS GS and MLS GP in the LAND mode will remain amber if a green VERT PATH, ALT, or FPA mode is demoded. In addition, if the autopilot is in the AUTO mode, the AUTO mode will be changed to VCWS.

11)   Pressing a mode button with an amber light status will cause that mode to be changed to a light-off status. (Note the exception that CAS turns green if the amber CAS button is pushed.)

FUNCTIONAL DESCRIPTION OF THE PRIMARY FLIGHT DISPLAY WHILE IN THE VELOCITY VECTOR OR AUTO CONTROL MODES

General Layout and Color Coding (Figure 7)

General--Figure 7 shows a color print of the primary flight display (PFD) in the velocity vector display format. The figure shown contains more guidance and situation information than are actually available simultaneously to illustrate color coding and location of the information.

The velocity vector display format contains the pitch, bank, and attitude symbols that are typically shown on electromechanical or EFIS display formats. The pitch scale rotates and translates with respect to the pitch and bank attitude of the airplane in the normal manner of a typical attitude indicator instrument.

The airplane airspeed and Mach number are shown in the grey area on the left-hand side of the display. The actual airspeed of the airplane is shown in a box in the middle of the airspeed scale. The airspeed scale moves up or down when the speed of the airplane changes. The Mach number of the airplane is shown on the top of the airspeed scale.

The altitude and vertical speed of the airplane are shown in the grey area on the right-hand side of the display. The actual altitude of the airplane is shown in a box in the

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middle of the altitude scale. The altitude scale moves up or down when the altitude of the airplane changes. The vertical speed of the airplane is shown in thousands of feet per minute on the right side of the altitude scale.

The PFD contains annunciation labels of the guidance that is currently driving the autopilot or the flight director and the corresponding situation information being shown in each of the corners of the display. The normal color coding of this information corresponds to whether the guidance and situation information is in an active status (green), an armed status (amber), or in a momentarily pilot-selected status (blue).

A momentarily pilot-selected status (blue) means that the situation information is shown for 8 seconds and then automatically removed from the display. This blue status occurs when there is not enough information defined for the guidance or situation information to be displayed, no valid radio signals received, or the pilot has not pressed an engage button on the flight control system mode control panel.

Individual symbology will be discussed in more detail in the following sections.

Airplane Situation Information (Figure 8)

Figure 8 shows the PFD with the airplane in a descending right turn passing through 30,340 ft at 280 knots calibrated airspeed (Mach 0.743). The velocity vector control wheel steering (VCWS) mode has been selected as indicated by the annunciation label in the upper left-hand corner of the PFD. No other guidance on the MCP has been selected since no other annunciation labels are shown on the PFD.

Pitch Attitude Symbol (Circle 1)--The pitch attitude symbol moves up or down relative to the pitch scale. In this figure, the pitch attitude of the airplane is 2 degrees below the horizon.

Commanded Flight Path Angle of the Airplane (Circle 2)--The FPA wedges show the pilot what flight path angle the flight control system will be controlling the airplane to maintain. This commanded angle is inertial (earth) referenced rather than air mass referenced.

The FPA wedges symbol remains stationary in the display with the tips of the wedges pointing to the actual airspeed and altitude boxes. The pitch scale moves relative to the FPA wedges.

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During most normal flight operations, the pilot will use the FPA wedges symbol to primarily control the vertical and lateral maneuvering of the airplane. The flight control system will control the attitude of the airplane to attain the commanded flight path angle and bank angle.

The height of the diamond in the center of the FPA wedges is equal to one degree on the pitch scale. This diamond is normally transparent (not filled with a color--as shown in this figure). However, when operating in the VCWS flight control mode, the diamond will be filled with an opaque white color when the PFD wedges have been positioned to a flight path angle close to zero. A white opaque diamond indicates that the VCWS flight control mode will maintain the current altitude of the airplane. An example of this mode is shown in figure 12.

Speed Change Predictor Bar (Circle 3)--The speed change predictor bar indicates to the pilot the predicted speed that will be attained in the next 10 seconds based on the current aircraft inertial acceleration. The end of the bar may also be used to indicate the flight path angle that can be currently commanded to be flown and still maintain approximately the same speed. In this figure, the speed will be reduced approximately 4 knots in the next 10 seconds, or, if it is desired to maintain the present speed, the flight path angle of the airplane should be lowered approximately 2 degrees.

Bank Angle Indicator (Circle 4)--The bank angle indicator indicates the bank angle of the airplane. Note that it turns in the direction of the bank angle of the airplane (i.e., it is not a sky pointer).

Vertical Speed Indicator (Circle 5)--The vertical speed indicator indicates the vertical speed of the airplane in thousands of feet per minute. The scale remains stationary and the bar points to the current vertical speed of the airplane.

Guidance and Control Mode Annunciation (Figure 9)

General--Figure 9 shows the PFD with lateral and vertical guidance and flight control modes selected. All guidance and corresponding situation information that are currently selected on the MCP by the flight crew are labeled on the PFD. All guidance and situation information in an active status are shown with a green color. All guidance and situation information that is armed and that will become active when the proper capture criteria is satisfied are shown with an amber color.

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Annunciation Labels of the Flight Control System Mode and the Autothrottle System Mode Selected (Circle 6)--The top annunciation label shows the flight control system mode. This label will always indicate the particular mode that is active (green label). The selectable modes are Velocity Control Wheel Steering (VCWS), Attitude Control Wheel Steering (ACWS), or Autopilot (AUTO).

In this figure, VCWS is selected. To the right of the VCWS or the ACWS label are two control input indicators. These indicators show if there are control inputs being made to the control wheel steering system in either the vertical or lateral axis. In this figure, the triangle indicates that a nose up pitch input is being made and the small vertical line indicates that no lateral input is being made through the side-arm controller.

The annunciation label, located just below the flight control system annunciation label, can show one of two selectable autothrottle system modes. The first mode is AT CAS where the autothrottles will control the engines to maintain the selected airspeed. This mode may be active (green label) when the CAS button on the MCP has been pressed or armed (amber label) when a desired airspeed has been inserted on the MCP. When in the armed status, the autothrottles are not controlling the engines.

The second mode is AT 4D where the autothrottles will control the engines to maintain a ground speed as a function of a 4D (time) programmed path. This mode may be active (green label) or armed (amber label) when selected. When in the armed status, the speed bug on the airspeed scale is shown with an amber color and the autothrottles are <u>not</u> controlling the engines.

When no autothrottle mode is selected, no annunciation label or speed guidance are shown.

Current Active Waypoint Name (Circle 7)--The name of the current active waypoint is displayed in the upper right-hand corner of the PFD. The name is displayed in green and will be automatically changed as the waypoint is passed. No name will be shown if there is no active 2D flight path defined in the flight management system.

Active and Armed Lateral Guidance Modes Selected (Circle 8)- The lower left-hand side of the PFD shows the annunciation labels of the lateral guidance modes selected that are in an active status and in an armed status. The active lateral mode is always shown as the top label in a green color. The armed lateral mode is always shown as the bottom label in an amber color. These mode annunciations will change

automatically when the armed mode capture criteria are satisfied.

The modes and labels that may be shown in this area are:

LABEL	SITUATION, GUIDANCE AND COMMANDS
TKA SEL	Track angle selected on the MCP
HOR PATH	Horizontal path programmed in the FMS
ILS LOC	ILS localizer tuned on the radios
MLS AZ	MLS azimuth tuned on the radio

Active and Armed Vertical Guidance Modes Selected   (Circle 9)--The lower right-hand side of the PFD shows the annunciation labels of the current active and armed status of the vertical guidance modes selected that are in an active status and in an armed status. The active vertical mode is always shown as the top label in a green color. The armed vertical mode is always shown as the bottom label in an amber color. These mode annunciations will change automatically when the armed mode capture criteria are satisfied.

The modes and labels that may be shown in this area are:

LABEL	SITUATION, GUIDANCE AND COMMANDS
ALT ENG	Altitude hold selected on the MCP
FPA SEL	Flight path angle hold selected on the MCP
VERT PATH	Vertical path (3D path) programmed in the FMS
ILS GS	ILS glide slope tuned on the radios
MLS GP	MLS glide path tuned on the radio
FLARE	Flare (only when in an autoland mode)

VCWS Track Angle Sub-Mode Symbol (Crows Foot)   (Circle 10)-- The lateral axis of the VCWS flight control mode operates in either of two sub-modes; bank angle hold or track angle hold. When in a wings level attitude, the track angle sub-mode will maintain the current commanded track angle of the airplane. The current commanded track angle is shown by the crows foot (Circle 10). The commanded track angle (and corresponding movement of the crows foot) may have small adjustments made to it through a trim button on top of the side-stick controller handle. When fine adjustments are made through the trim button, the crows foot will remain on the PFD. When adjustments to the commanded track angle are made by banking the airplane with the side-stick controller, the crows foot will be removed until the bank angle is brought back to approximately wings level.

Airspeed and Altitude Information and Guidance (Figure 10)

Mach Number of the Airplane   (Circle 11)--The Mach number is not displayed when less that 0.400.

Airspeed of the airplane *(Circle 12)*--Present calibrated airspeed of the airplane presented in knots.

Autothrottle CAS Mode Annunciation *(Circle 13)*--This mode status annunciation may be green (active) or amber (armed).

CAS Airspeed Bug *(Circle 14)*--This bug indicates the airspeed selected on the flight control MCP. It moves up and down the airspeed scale and its center, noted with a notch, is positioned on the selected airspeed. It is shown in green when the autothrottle is turned on (active) and is shown in amber when the autothrottle is turned off but in an armed status. When an airspeed has been selected that is not shown on the airspeed scale, the bug will be parked at the top or bottom of the scale with only half of the bug showing.

CAS Numerical Label *(Circle 15)*--This label shows the numerical value, in knots, of the selected airspeed. It will be shown in either an amber color to indicate an autothrottle armed status or green color to indicate an autothrottle active status.

FPA Reference Bar *(Circle 16)*--The flight path angle reference bar is positioned on the pitch scale to indicate the commanded flight path angle. The FPA reference bar may be driven by the VERT PATH mode or, as shown in this figure, the FPA mode. If both of these vertical axis modes are selected (i.e., VERT PATH armed and FPA active), the FPA reference bar will be green and driven by the active vertical axis mode (FPA).

Annunciation Label of the Active Vertical Axis Guidance Mode *(Circle 17)*--In this figure, the active vertical guidance is FPA (green label) with a commanded flight path angle of 3.1 degrees down.

Altitude of the Airplane *(Circle 18)*--Present barometric altitude of the airplane in feet above sea level.

Circle 19. Altimeter setting. Barometric altimeter setting in inches of mercury. The setting is made through the FMS CDU.

Guidance and Control Mode Annunciation (Figure 11)

Annunciation Label of the Active Lateral Axis Guidance Mode *(Circle 20)*--In this figure, HOR PATH is shown with a green label which corresponds to the green horizontal path error scale and bug (circle 21).

Horizontal Path Error (Circle 21)--The horizontal path error is shown in green if active and amber if armed. Full scale bug deflection is normally ±7500 feet When on an approach to a runway, the full scale deflection will emulate an ILS localizer by being reduced linearly until crossing the threshold of the runway where full scale deflection is ±350 feet.

The horizontal path error scale (no bug) may be shown in blue for 8 seconds if no path has been programmed in the FMS CDU and HOR PATH was selected on the MCP.

Desired Track Angle Symbol (Circle 22)--The desired track angle symbol shows the desired track angle along the horizontal path if the HOR PATH mode is active or the selected track angle if the TKA mode is active. The active lateral axis mode will be annunciated with a green label on the PFD. In this figure, the desired track symbol is being driven by HOR PATH since it is the active (green label) lateral axis guidance mode.

Annunciation Label of the Active Vertical Axis Guidance Mode (Circle 23)--In this figure, VERT PATH is shown with a green label which corresponds to the green commanded vertical path altitude bug (circle 24).

Commanded Vertical Path Altitude Bug (Circle 24)--This bug is positioned on the altitude scale at the commanded altitude of the 3D path programmed in the FMS CDU. The bug is green when VERT PATH is active and amber when VERT PATH is armed.

The vertical path altitude bug may be shown in blue for 8 seconds if a 3D path is not programmed in the FMS CDU and VERT PATH was selected on the MCP.

Annunciation Label of the Armed Lateral Axis Guidance Mode (Circle 25)--In this figure, ILS LOC is shown with an amber label which corresponds to the amber localizer dots and deviation bug (circle 26).

ILS Localizer Deviation Scale (Localizer Dots and Deviation Bug) (Circle 26)--The ILS localizer deviation scale and bug will be shown in green when the localizer capture criteria is satisfied; amber when a valid signal is received and LAND mode has been selected on the MCP; and blue for 8 seconds if no valid signals have been received and the LAND mode have been selected.

The same scale and bug is used for an MLS azimuth signal, when MLS is selected, except that the deviation bug shows AZ rather than LOC.

Annunciation Label of the Armed Vertical Axis Guidance Mode (Circle 27)--In this figure, ILS GS (glide slope) is shown

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with an amber label which corresponds to the amber glide slope dots (circle 27).

Glide Slope Deviation Scale (Glide Slope Dots) and Bug (Circle 28)--The ILS glide slope deviation scale and bug will be shown in green when the glide slope capture criteria have been satisfied and amber when the capture criteria are not satisfied but a valid glide slope signal is received.

The glide slope dots (without the bug) will be shown when the LAND mode has been selected on the MCP, the ILS has been tuned, and and the localizer signal has been received. If the LAND mode has been selected and no valid signals have been received, the glide slope dots will be shown as blue for 8 seconds.

The same scale and bug is used for an MLS glide path signal, when MLS is selected, except that the deviation bug shows GP rather than GS.

Decision Height Annunciation (Circle 29)--The decision height is adjustable from a knob adjacent to the PFD. When the decision height is adjusted to zero, the decision height annunciation disappears from the PFD.

The decision height annunciation is shown in grey until the airplane has attained a radar altitude equal to, or less than, the decision height. When below the decision height, it is shown in amber.

Radar altitude (Circle 30)--The radar altitude is shown in blue automatically when the airplane has a radar altitude less than 1000 feet. When the radar altitude is equal to, or less than, the decision height, it is shown in amber.

Horizontal and Vertical Path Modes to an ILS Capture
(Figure 12)

Annunciation Label of the Active Lateral Axis Guidance Mode (Circle 31)--In this figure, TKA and the track angle selected from the MCP is shown with a green label. This corresponds to the green desired track symbol (circle 32).

Desired Track Angle Symbol (Circle 32)--The desired track angle symbol shows the desired track angle along the horizontal path if the HOR PATH mode is active or the selected track angle if the TKA mode is active. The active lateral axis mode will be annunciated with a green label on the PFD. In this figure, the desired track symbol is being driven by the TKA mode since it is the active (green label) lateral axis guidance mode.

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Annunciation Label of the Active Vertical Axis Guidance Mode (Circle 33)--In this figure, ALT is shown with a green label. This corresponds to the green selected altitude label (circle 34) and the green altitude bug (circle 35). The label is shown in a green color when the ALT mode is in the active status and amber when in an armed status. The label is not shown when in a blue status.

Numerical Value of ALT   (Circle 34)--The value of the altitude selected on the MCP is shown here. It is shown with a green color when the ALT mode is the active vertical guidance mode, amber when the ALT mode is in an armed status, and blue for 8 seconds when the ALT knob on the MCP has been turned but the ALT select button has not been pushed.

ALT Bug   (Circle 35)--The ALT bug is positioned on the altitude scale at the selected altitude. If the altitude selected is not displayed on the altitude scale, the bug will be parked in either the upper or lower end of the altitude scale with only half of the bug showing. The bug is shown with a green color when ALT is the active vertical guidance, amber when ALT is in an armed status, and blue for 8 seconds when the ALT knob on the MCP has been turned but the ALT select button has not been pushed.

Figure 1.--NASA Transport Systems Research Vehicle B-737 airplane.
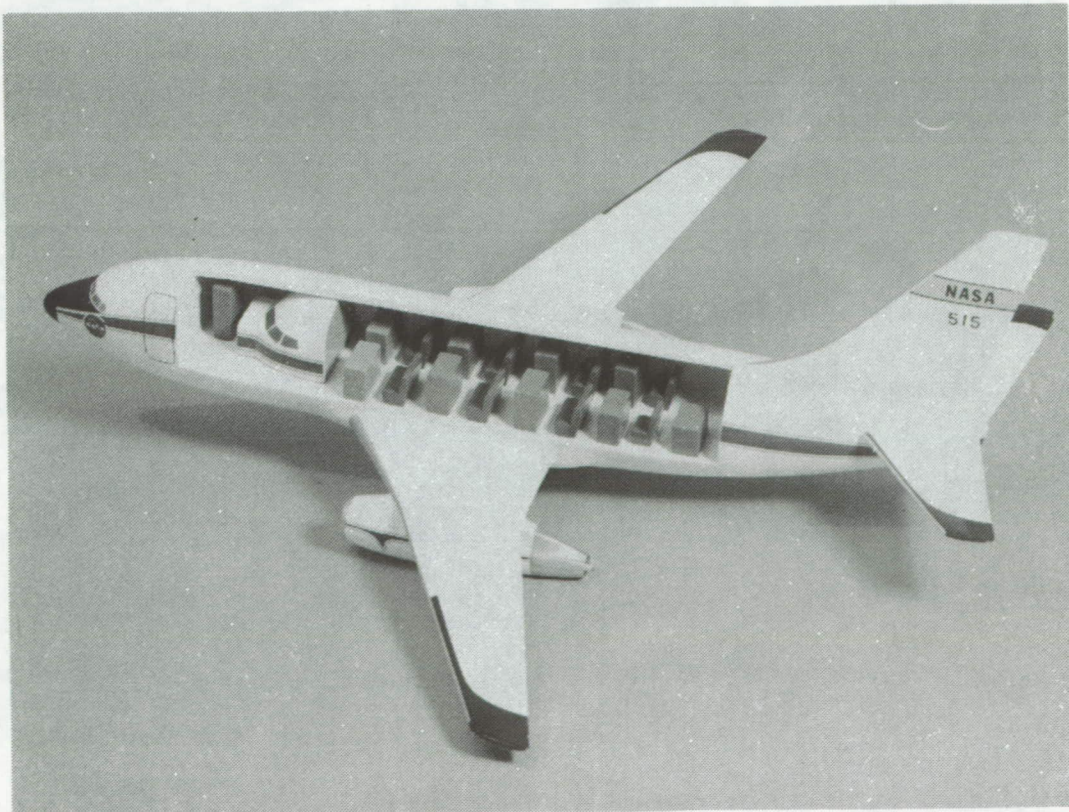
Figure 2.--Model of NASA Transport Systems Research Vehicle interior.

Figure 3.--NASA Transport Systems Research Vehicle research flight deck.

MODE CONTROL PANEL

| 250 | 33000 | - 3.1 | 320 |

○ CAS ENG   ○ ALT ENG   ○ FPA SEL   ○ TKA SEL

LAMP ○ TEST | VEL CWS | ATT CWS | AUTO | LAND | HOR PATH | VERT PATH | TIME PATH | DIM ○ | LAMP ○ TEST
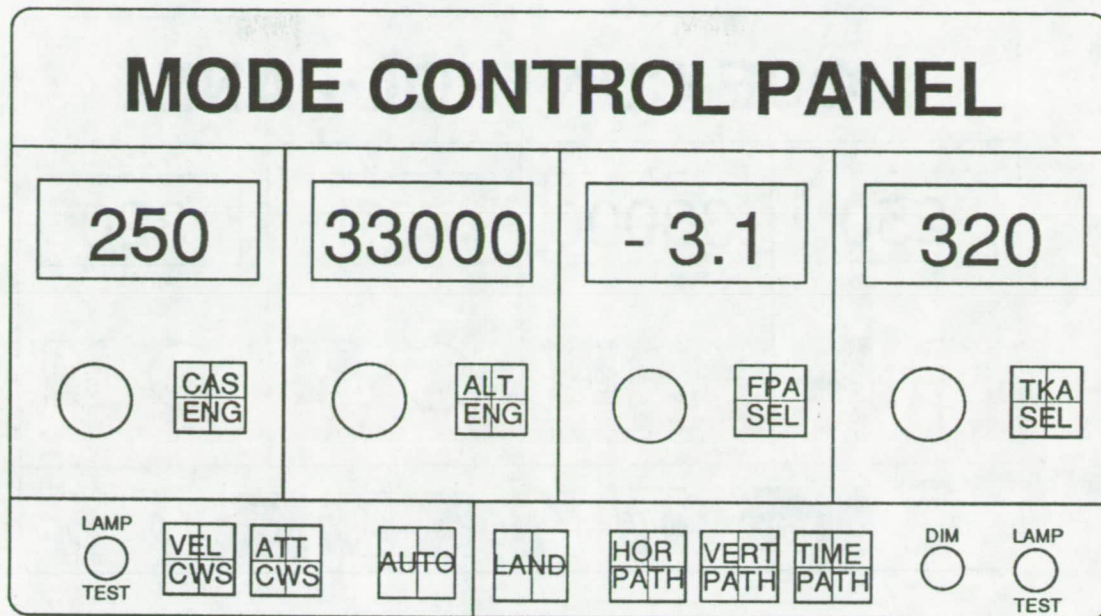
Figure 4--Flight control system mode control panel.

MODE CONTROL PANEL

| 250 | 33000 | - 3.1 | 320 |

○ CAS ENG   ○ ALT ENG   ○ FPA SEL   ○ TKA SEL

LAMP ○ TEST | VEL CWS | ATT CWS | AUTO | LAND | HOR PATH | VERT PATH | TIME PATH | DIM ○ | LAMP ○ TEST

CALIBRATED AIRSPEED AUTOTHROTTLE

AUTOPILOT

GUIDANCE

TIME PATH AUTOTHROTTLE
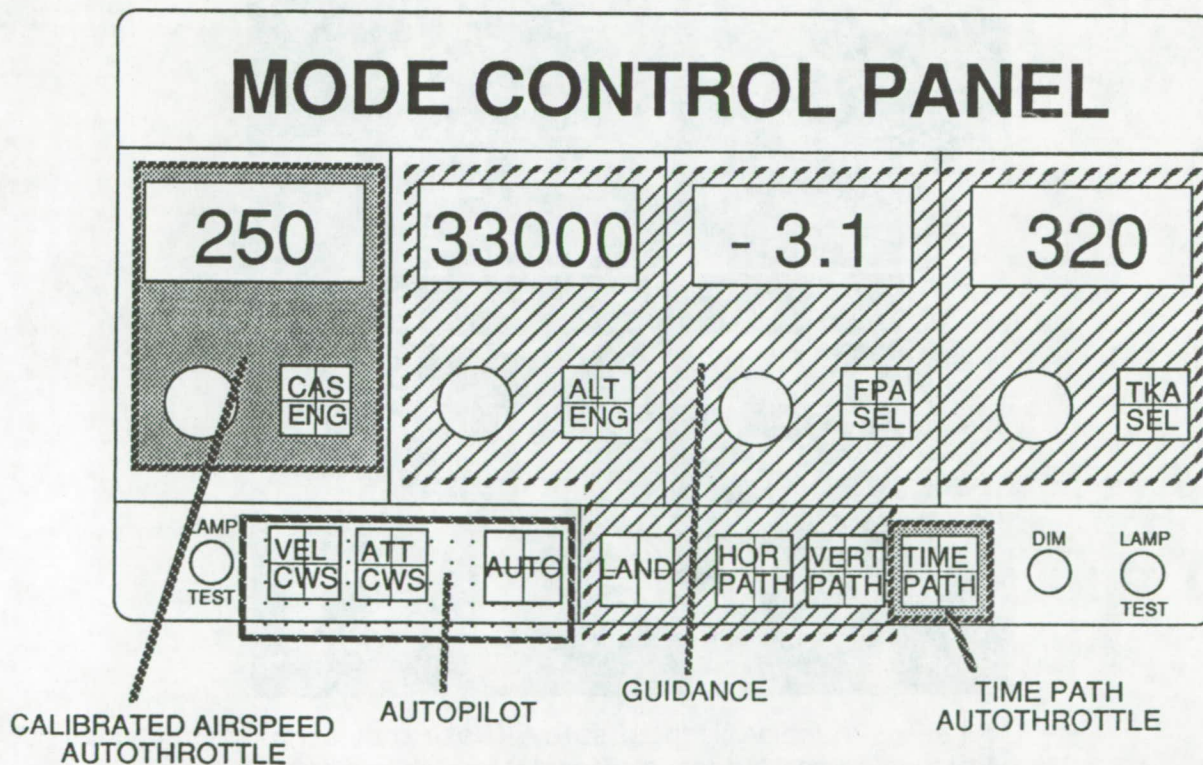
Figure 5--Flight control system mode control panel layout.
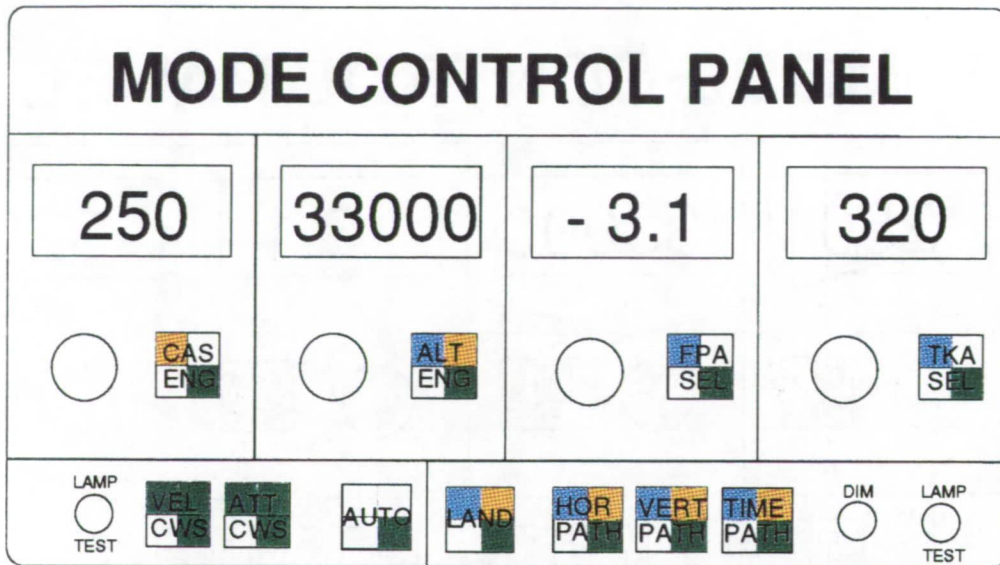
MODE CONTROL PANEL

Figure 6--Flight control system mode control panel lights.
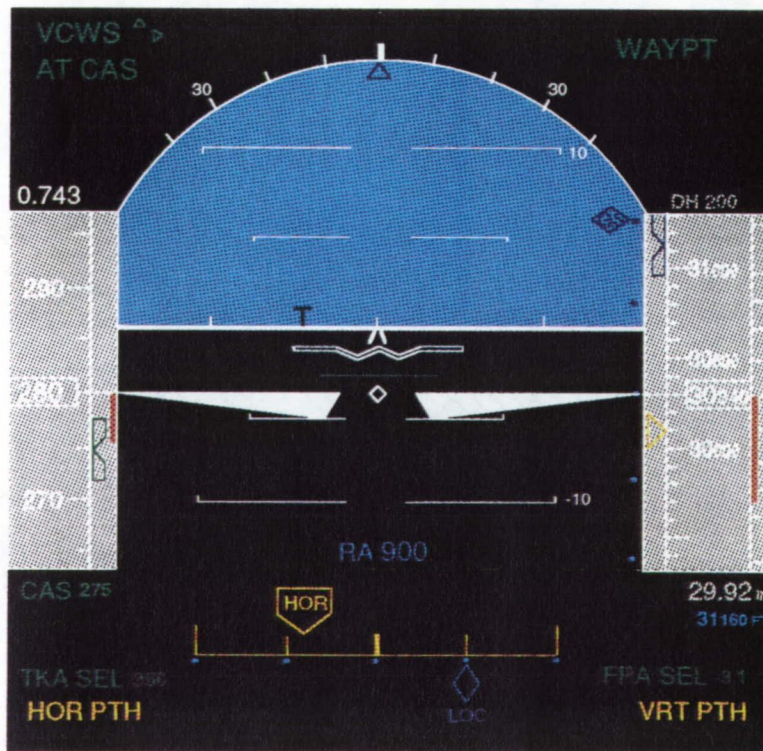
Figure 7--Primary flight display (Note that all of the situation and guidance information shown in this figure are not available simultaneoulsly.)
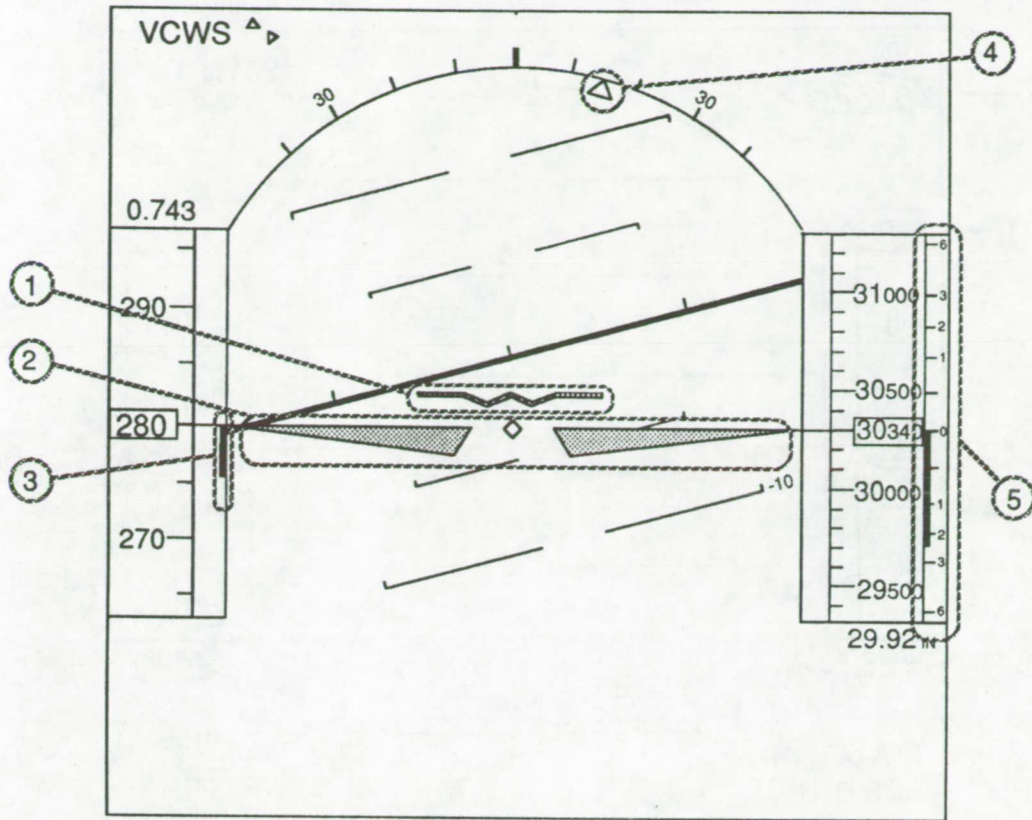
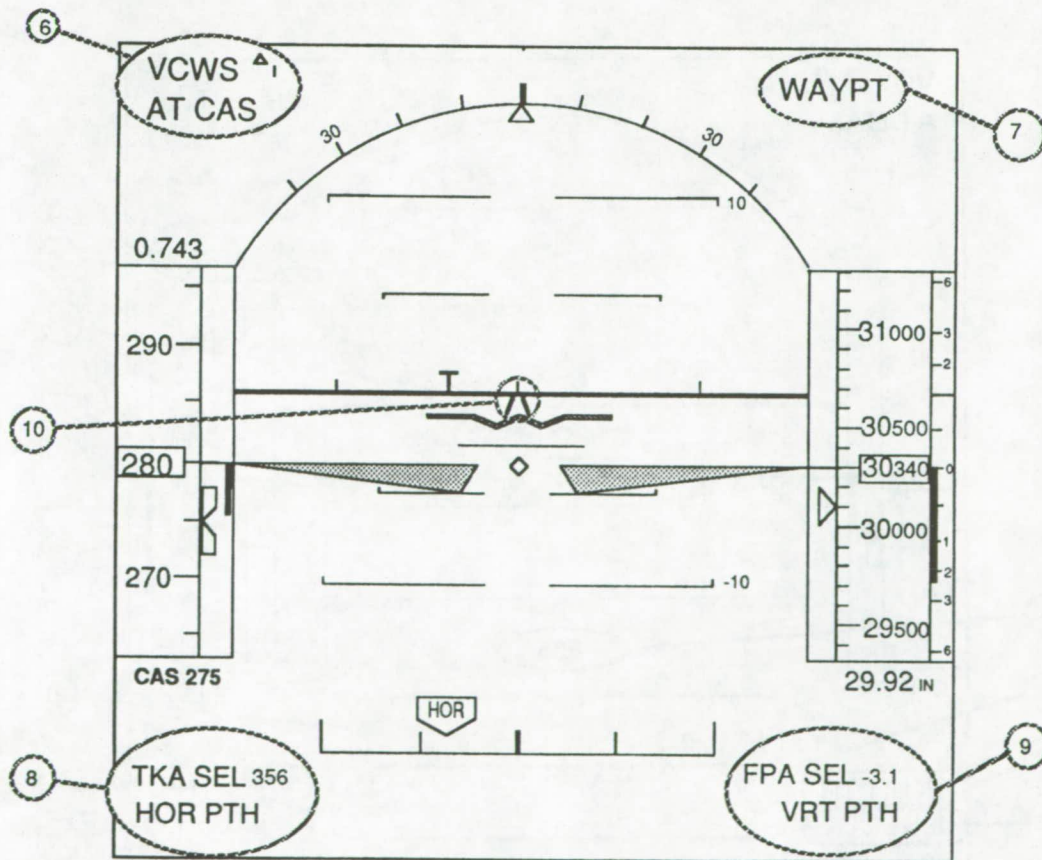Figure 8--Primary flight display with no selected mode control guidance.

Figure 9--Primary flight display with horizontal and vertical path guidance.
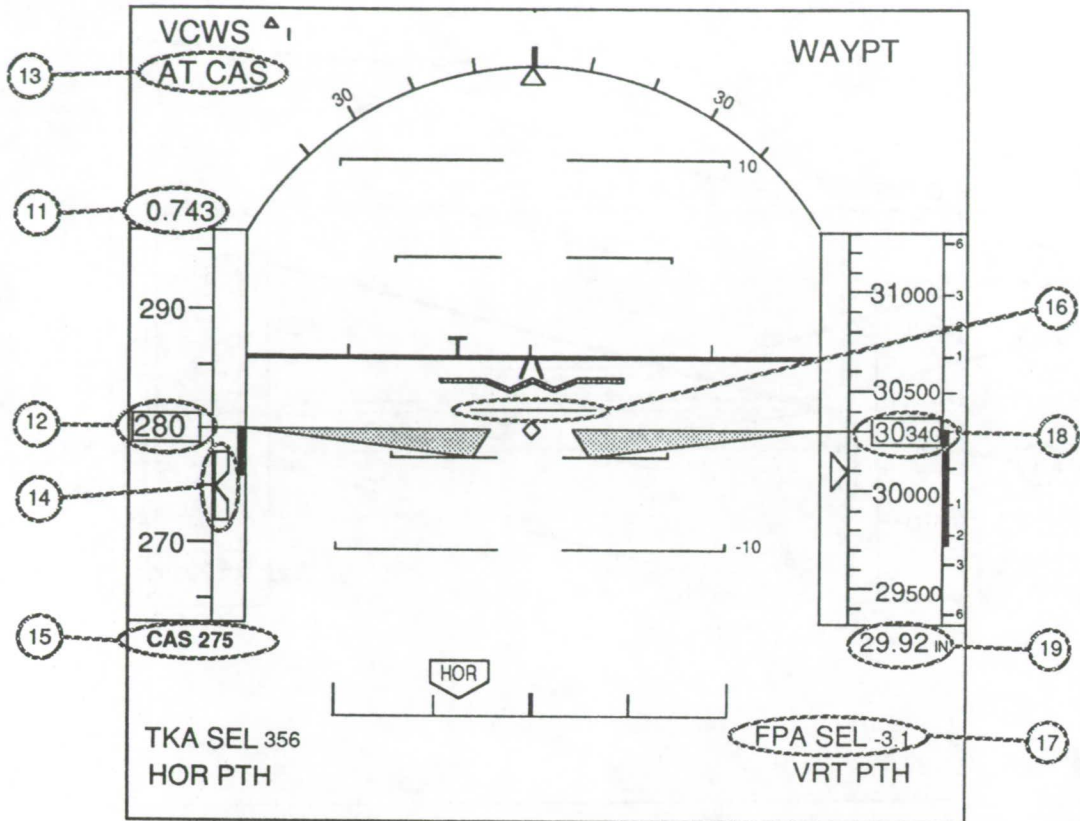
Figure 10--Primary flight display with the speed and altitude scales described.
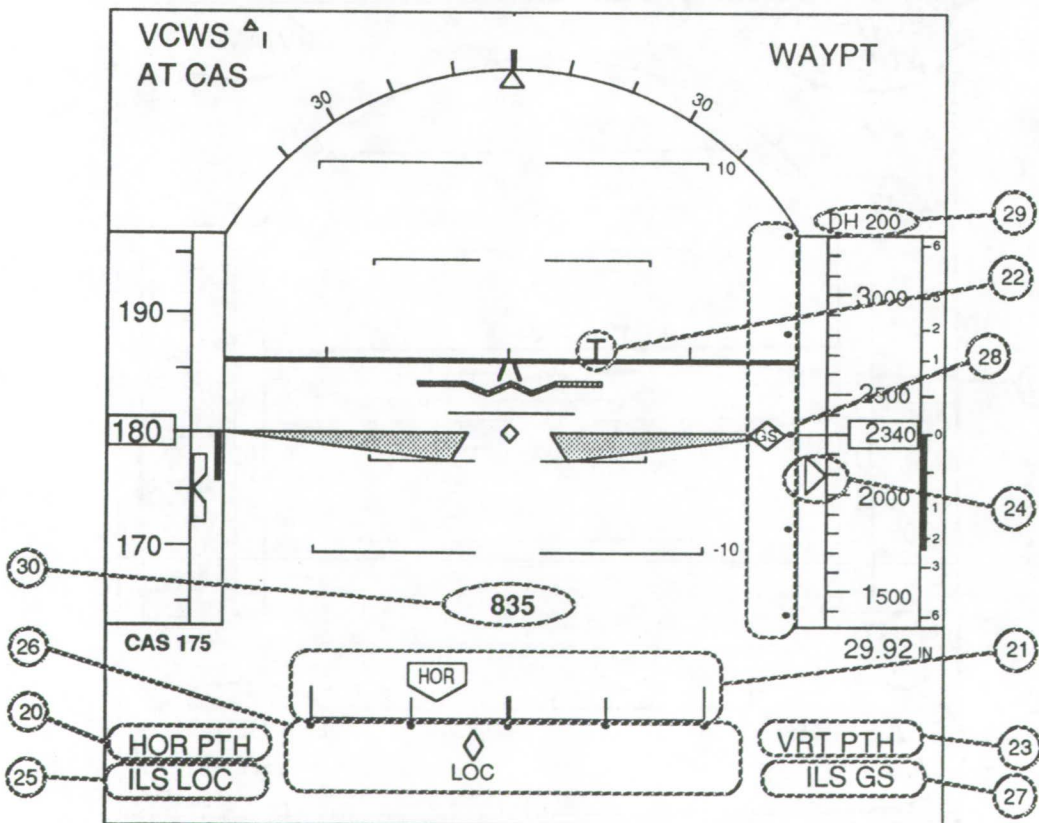

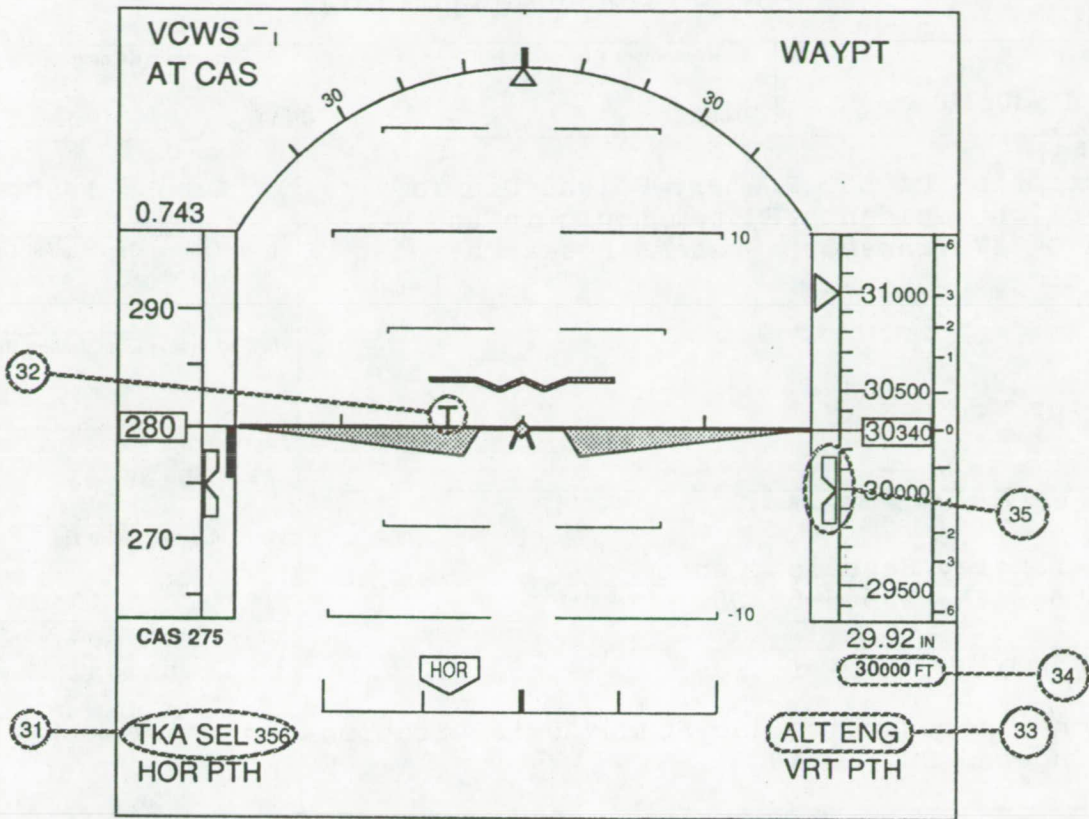Figure 11--Primary flight display with horizontal and vertical path modes.

Figure 12--Primary flight display with track select and altitude hold modes.

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15. Supplementary Notes

16. Abstract

A primary flight display format on an 8" x 8" CRT has been developed for the NASA Transport Systems Research Vehicle B-737-100 airplane. This primary display format has been integrated with the flight guidance and control system logic in support of various flight tests conducted with the airplane. This report describes the functional operation of the flight guidance mode control panel and the corresponding primary flight display formats.

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