A head up display for application to V/STOL aircraft approach and landing

Authors: Merrick, V. K., Farris, G. G., & Vanags, A. A.

SUMMARY

This paper presents nomenclature used in HUDs. Nomenclature is divided into four categories: (1) continuous and discrete input variables (continuous variables come from the aircraft sensors and discrete variables come from the operating-mode alternatives); (2) intermediate variables used in the description of the display-symbol drive laws; (3) constants; and (4) output variables (e.g., display coordinates).

Pilot perceptions of flight task difficulty can be considered a function of the quality of the technique used to display situation and guidance cues on the aircraft. HUD displays have become the preferred method of display because of the improvements of the 16” X 16” field of view (FOV) and sensor quality. The geometrical formats of where and how to display HUD sensor information has also been an item of research. In the early HUD formats, flight directors (in the form of ADI-type formats) were presented using error bars that moved relative to the plane’s “aircraft-body-fixed symbol.” Surrounding this was flight status information. The biggest issue with the early HUD design was that there was a dissociation rather than integration of the flight guidance information and status information. Thus, the pilot could “zero-out” a segment of data. A remedy for this problem was to change the format to one based on pursuit rather than compensatory tracking such that the pilot could monitor where the plane is going rather than where it is pointing.

Research over the years has focused on evaluating HUD designs for both the VTOL (Vertical Take Off and Landing) and STOL (Short Take Off and Landing) approach. The HUD general design requirements include:

1. Primary guidance should be simple, uncluttered, analog error-free, have a centered flightpath symbol and support assimilation with a single glance.
2. Guidance graphics and dynamics need to be represented.
3. Graphics should be conformal with the outside visual scene.
4. Flight and control status information should fan-out from the guidance information zone in some logical order.
5. Flight envelope limits should be drawn.
6. All control limits, not clear from pilot-control positions or forces, should be shown.
7. Clutter should be minimized.
8. Relative locations of the guidance and flight info should match those of the pilot’s controls.
9. The display should provide the pilot with complete flight status info at all times.

The approach and hover were the two modes of landing covered in this paper. For the purpose of this summary, most of the discussion about hovering is not presented. Both
modes of HUD operation provide vertical and lateral guidance represented by a “ghost” aircraft, which identifies positioning of an aircraft in front of them and then modeling what perfect landing actions would be. The vertical and lateral controls are indicated by the flightpath symbol, which gives the direction of the plane’s inertial velocity vector. The pilot needs to fly the plane so the ghost and flightpath coincide.

Sensor Requirements

HUDs are designed to be equipped with full inertial navigation systems providing positions, velocities and accelerations. Certain pilot-selected info must be provided to the display computer:

(1) runway heading,
(2) runway altitude,
(3) approach glideslope,
(4) approach deceleration,
(5) initial and final station-keeping points relative to the desired touchdown point,
(6) final approach track heading and
(7) ship type (landing-pad geometry).

The HUD approach display includes aircraft fixed symbols. The display construction begins with fixed elements such as engine RPM, Range (DME), aircraft reference symbols and nozzle angle.

Attitude and flightpath references include a representation of roll, pitch and heading. The pitch scale is presented in increments of 4 degrees relative to the horizontal line. Solid bars are positive pitch angles and dashed bars are negative pitch angles. Heading is perpendicular from the aircraft reference symbol to the horizon (see Page 7).

There are only certain symbologies that are used in certain display modes. They include the flightpath (velocity vector), the airspeed, the altitude and altitude rate digits, the longitudinal acceleration caret and the longitudinal guidance error ribbon. This set of symbols moves with the flightpath symbol as a group and actually rolls with the aircraft. An example of this symbology is below:
The flightpath symbol is central to both the approach display and the transition display. The cross track angle is the difference between the aircraft’s heading and its velocity vector, relative to the station-keeping point. It is a function of the winds and the aircraft sideslip. At low speeds, the sideslip angle becomes very sensitive to changes in lateral velocity. To maintain the flightpath symbology within the HUD FOV at low airspeeds, the symbol drive laws are modified so that the symbol indicates lateral and vertical velocities rather than flightpath angles. The flightpath symbol is the primary element used during the approach and transition. Quickening logic (logic that expedites decision making) has been added to the control inputs, which significantly reduce pilot workload; especially in IMC landing approach tasks (Page 9). During the approach, the altitude, vertical velocity and airspeed are displayed digitally. To avoid any possibility of obscuring the symbology, digital readouts are fixed relative to the flightpath symbology and they move together. The acceleration caret indicates the horizontal acceleration. The acceleration caret is scaled, such that the caret always indicates the zero longitudinal acceleration position of the flightpath symbol. The principal utility of the flightpath concept is that it gives the pilot a preview of the steady-state flight path angle. It provides a timely indicator of the presence of wind shear. Longitudinal or speed guidance is presented only if such guidance is selected by the pilot. If the pilot desires to capture and hold a given airspeed (or groundspeed) a velocity error line appears that is attached to the longitudinal acceleration caret. This is used in decelerating the aircraft to hover.

The ghost aircraft symbol provides the vertical and lateral guidance during the approach. The ghost can be thought of as being an aircraft ahead, exhibiting perfect approach performance. The ghost also performs perfectly coordinated turns. A runway symbol is provided to give the pilot awareness of the location of the plane to the location of the final destination.

Concluding remarks (Page 44)
In the approach mode, the flightpath symbol gives the true direction of vertical flight only. Because of HUD FOV restrictions, the lateral motion of the flightpath symbol has to be reduced to only 30% of its initial full value. The fact that this is reduced and that the yaw scale is conformal, the pilot gets an inaccurate impression of the lateral motion of the aircraft.

The HUD format employs neither color nor occlusion because the equipment does not permit it. However, color could be beneficial in the differentiation and highlighting of various symbols to alleviate the feeling of being overwhelmed by a profusion of symbols. The authors are unaware of any studies about occlusion but this concept could help out to produce an illusion of depth and help classify symbols into a hierarchy.

COMMENTS

This document was difficult to follow because it does not explain what type of symbology display was used for specific types of approaches.