The history of the head-up display dates back to world war ii essay sample

War

Abstract

The history of the head-up display dates back to World War II. Since then, the head-up display has gone through a variety of changes and upgrades. Both the Airline Pilots Association and the Airline industry pursued the development of the head-up display because of the advantages it offers. As with any new technology, the head-up display has advantages and shortfalls. Education however, is the key to fully understanding new technology including the head-up display. With proper cockpit resource management training, the advantages the head-up displays bring to aviation result in the safest approach to flying.

Head-up display (HUD): A Safer Approach

The origin of the head-up display (HUD), a modern miniature instrument panel, was the reflective gun sight technology of World War II. This technology, Ellis explained, “ used collimated displays reflected from a semi-transparent glass” which evolved into several different types of head-up displays, such as the traditional head-up display, reflective head-up display, and the GA head-up display (Ellis, 2000, p. 1). This evolution of the head-up display from World War II shows how technological processes, economics, and safety can all interact with each other effectively to create a safer approach to flying (Hawkins, 2000, p. 252). “ The traditional head-up display uses a refractive optical design with combining glass to superimpose the head-up display symbols and the pilot’s view of the real world” (Ellis, 2000, p. 2). In this kind of system, the crewmember views the image on a semi-transparent combining glass, after a set of rays are produced from the image passing through a lens assembly (Ellis, 2000, p. 2).

Compared to head-up displays with flat combiners, the reflective head-up display has the ability of a larger instantaneous field-of-view when used with optical power. This ability reduces the need for crewmembers head motion in order to view the symbology on the head-up display (Ellis, 2000, p. 3). According to Ellis, the GA head-up display “ uses a single powered optical element, and a curved ellipsoidal mirror as the combiner/collimator. This allows for a much more compact optical design.” However, because of the design, optical distortions are possible with the GA head-up display including pincushion distortion and size aberrations (Ellis, 2000, p. 3). The different types of head-up displays all share the same general human factor advantages, problem areas, and crew training requirements, and my focus will be on these similarities (Ellis, 2000, p. 3).

There are several advantages of using a head-up display for civil aviation. Utilizing the head-up display increases performance of cockpit members and improves safety (Alba, 2000, p. 6). To ensure optimal aircraft operation, crewmembers rely on information from multiple sources of information (Fadden, 2000, p. 1). The cockpit instrument panel was traditionally located under the window and glare shield, and this is where all the primary cockpit instrument displays such as speed, attitude, altitude, and heading were located (Fadden, 2000, p. 1). The location of the instrument panel caused crewmembers to scan between the instrument panel and the outside world during different phases of flight (Fadden, 2000, p. 1). While scanning between the different domains, the crewmember’s eyes had to adjust between near, far, and in different lightings (Fadden, 2000, p. 1). The original objective for the head-up display was to provide an improved situational awareness during lower visibility flights for increased safety (Hawkins, 2000, p. 252).

The head-up display can ease “ the transition from head-down flying on an instrument approach to head-up flying for the visual landing” (Hawkins, 2000, p. 252). Both the Airline Pilots Association (ALPA) and the Airline industry pursued the development of the head-up display, but for different reasons (Hawkins, 2000, p. 254). The Airline Pilots Association believed that the development of the head-up display would improve the safety aspect of operating the aircraft during landings below the current weather limits (Hawkins, 2000, p. 254). The Airline industry believed that the installation of the head-up display would reduce diversions in schedules, thus reducing costs of missed flights by improving scheduling regularity (Hawkins, 2000, p. 254). Scheduling regularity is improved because landings can be permitted in lower visibility than without the head-up displays installed (Hawkins, 2000, p. 254). Another benefit of the head-up display is improvement in situational awareness (Fadden, 2000). This improvement is possible because with a head-up display the near domain of instrument information is attainable by the crewmember without forfeiting the far domain of the outside world (Fadden, 2000).

This parallelism of imagery reduces the scanning time for crewmembers, which reduces crew fatigue, enhances tracking of instruments and detection performance during all flight phases to include take-off, climb, cruise, good visibility approaches, automatic landing, monitoring, roll-out guidance, and wind shear protection (Fadden, 2000, p. 1, Hawkins, 2000, p. 253). The head-up display was not only developed as an aid for visual flight. It can also be used for recovery from abnormal attitudes by enhancing the awareness of airspeed with indication of airspeed management and symbols for air mass flight paths (Ellis, 2000, p. 1). Instrument approaches can also be enhanced because of symbology that incorporates steer point icons to the view field of the head-up display, which provides geographic situational awareness (Ellis, 2000, p. 1). No one in the aircraft industry can argue that time has proven that the major advantages of using the head-up display have clearly been established.

The crewmember’s workload has been reduced, flight accuracy has increased, flight safety is increasing, and direct visualization of trajectory is possible (Ellis, 2000, p. 1). In Fadden, Wickens, and Ververs paper, Costs and Benefits of Head up Displays: An attention perspective and a Meta Analysis, they used twenty-two experiments, and when all phases of flight were considered collectively for both tracking and detection, an overall benefit for the head-up display was determined (p. 5). In particular, the head-up display showed benefits in tracking for landing and taxi operations and event detection during cruise operations (Fadden, 2000, p. 5). Despite all the advantages, head-up displays still have not been installed in all aircrafts. Lack of use is because there are shortfalls with the head-up display as well (Ellis, 2000, p. 1).

According to Ellis, “ cost and size” are the two reasons for not installing head-up displays in all aircrafts (Ellis, 2000, p. 1). The cost of a head-up display ranges from seventy thousand to five hundred thousand dollars and the expense is considered too costly for the advantages the head-up display offers for many applications (Ellis, 2000, p. 1). There are different factors that determine the cost of a head-up display. The specification for brightness, the use of projection lenses and reflecting holograms to meet brightness specifications, the wide field of view specifications, and the need for dedicated electronics all contribute to the expense of the head-up display (Ellis, 2000, p. 2). The specification of brightness is due to the human factors involved in using a head-up display such as crewmember fatigue when monitoring head-up displays for long periods of time (Hawkins, 2000, p. 250). The physical size of the head-up display is the second reason that Ellis gives for not having head-up displays in all aircrafts (Ellis, 2000, p. 1).

The space in many large airliners is very compact and limited space is available (Ellis, 2000, p. 1). In most corporate jets or smaller planes, space is not available at all for the head-up display (Ellis, 2000, p. 1). The fundamental influence on the space available in aircraft flight decks is the aerodynamics of the aircraft. This influence of space is because of the windshield and design eye locations (Hawkins, 2000, p. 276). The design eye position must be identified and the head-up display must be located within the design eye position to maximize operation (Ellis, 2000, p. 2). The design eye position is a sort of “ cockpit keyhole” (Hawkins, 2000, p. 120). The design eye is what the manufacturer’s design equipment around, believing the crewmember’s eye will be positioned there during all phases of flight

(Hawkins, 2000, p. 120). The proper positioning of the design eye is important, because through the design eye the crewmembers must be able to sufficiently see the near domain and the far domain without much movement (Hawkins, 2000, p. 121). Crewmembers have reported that they do not routinely use the head-up display because their seating habits need to be changed in order to be in the eye box of the head-up display (Alba, 2000, p. 5).

According to Alba “ the eye box has been centered on the Design Eye Position of the cockpit” (Alba, 2000, p. 5). With all the variables that must be accounted for and designed around it is very hard to add and effectively use head-up displays in existing aircraft flight decks. Other disadvantages of the head-up display that involve human factors are the livewire to software interface of symbology, and software development (Hawkins, 2000, p. 250). The symbology is presenting flight data in a way that the crewmembers can utilize the information (Ellis, 2000, p. 7). The problem is that crewmembers can interpret the same information differently, and that is why changes in symbology have been made since the original versions (Ellis, 2000, p. 7). Switching and time-sharing of information, or “ what should appear where and when on the screen,” are also human factors that need to be considered during software development for the head-up display (Hawkins, 2000, p. 250). Other factors that are not completely understood are that information read from a head-up display is not processed by the brain as fast as from printed material, which delays response time in emergency situations (Hawkins, 2000, p. 25, 251). Some crewmembers that have had questionable experience with technological advances challenge the reliability of the head-up display and question whether or not the output of information on the head-up display is reliable and accurate.

This uncertainty leads to low utilization by the crewmember and a feeling that the pilot should remain in control, and that is why data integrity must be insured by the head-up display software (Hawkins, 2000, p. 252, Ellis, 2000, p. 9). Ellis explains, “ Data integrity can be thought of as the likelihood of not displaying incorrect data without clear and effective annunciation” (p. 9). In some cases the data integrity requirements have been relaxed because the head-up display is not considered a primary flight display, and this relaxation is also a reason for the crewmembers uncertainty (Ellis, 2000, p. 9). Data availability is also very important when it comes to crewmember acceptance (Ellis, 2000, p. 9). To ensure crewmember confidence, it is important for the information displayed to be relevant to the situation and correct (Ellis, 2000, p. 9). The head-up display monitor can also become cluttered with complex imagery (Fadden, 2000).

The clutter is created when far domain images and near domain images are overlapped (Fadden, 2000). This overlapping of information makes it difficult for operators to identify required information (Fadden, 2000). Another human factor of head-up display usage is attentional tunneling (Fadden, 2000). Attentional tunneling occurs when a crewmember fails to attend to the far domain while excessively focusing his attention on the head-up display symbology (Fadden, 2000). Factors that relate to attentional tunneling are the expectation that a certain event will occur and a surprising event (Fadden, 2000). Expectation can also affect the performance of crewmembers while using the head-up display (Fadden 2000, p. 5). Fadden explains, from the focused test in his paper,

This result indicates that when crewmembers are expecting targets to appear, they perform best when using a HUD. However, when pilots are not expecting targets to appear (such as when a surprising runway incursion event is presented near the end of a study), performance is significantly degraded when a HUD is used instead of a HDD (p. 5).

Psycho-physiological human factors are also a shortfall of a head-up display (Hawkins, 2000, p. 254). According to Hawkins (2000)

Psychophysiological Human Factors questions are generated as a direct result of superimposing a synthetic display on to the real-world picture. What field of view, horizontally and vertically, is required? Should the display provide simply raw data such as displacement from flight path, or should it display command information? And what selection possibilities should be given to the pilot? How is the threshold of unacceptable deviation displayed and how reliable is manual take-over close to the ground? How is the hardware located ahead of the pilot’s eyes to be delethalized to provide impact protection? How much light transmission loss through the combiner or windshield coating can be accepted?

Disrupted visibility is another shortfall with the head-up display (Fadden, 2000). Low contrast of the head-up display and the high brightness of the outside world cause disrupted visibility of observed instruments for the operator (Fadden, 2000). Many of the shortfalls discovered with the head-up display can be eliminated through proper training of crewmembers.

Crewmember training is very important for the acceptance of the head-up display by crewmembers (Alba, 2000, p. 5). Some crewmembers report that they do not use the head-up display routinely because of limited simulator training time (Alba, 2000, p. 5). Most crewmembers show very high acceptance for the head-up display after the initial simulator training (Alba, 2000, p. 5). Following the initial simulator and classroom training, crewmembers see the importance of head-up display to monitor aircraft trajectory and to perform manual maneuvers of the aircraft. This technology is why the head-up displays are more accepted by crewmembers (Alba, 2000, p. 5). All crewmembers should receive initial training, because the training on head-up display usage in aircrafts does not impede the crewmember’s ability to return to an aircraft without the head-up display installed (Alba, 2000, p. 5). Once a crewmember learns of the benefits of using a head-up display, when he returns to a conventional style aircraft it is reported that he makes statements like, “ It’s bad. Now, I need this stuff, ” but crewmember performance has not been reported to have declined (Alba, 2000, p. 5).

Another part of the training needs to address the non-flying crewmember issues (Alba, 2000, p. 6). The non-flying crewmember must be aware of what is expected of him from the captain of the aircraft (Alba, 2000, p. 6). While using a head-up display, the captain is less focused on the peripheral cues and more focused on the head-up display (Alba, 2000, p. 6). This is why the non-flying crewmember must be aware of what the captain is able to detect in his peripheral visual field, so communication is essential for crewmember coordination (Alba, 2000, p. 6). With proper training, the benefits of the head-up display with regard to safety will be agreed upon by most crewmembers (Alba, 2000, p. 6). This agreement between crewmembers will be even greater when it comes to manual handling in emergency situations, or even just in times of difficultly (Alba, 2000, p. 6). Without training being properly stressed and conducted, crewmembers will feel that the use of the head-up display is not needed for routine operations (Alba, 2000, p. 6).

This feeling is largely due to habit (Alba, 2000, p. 6). As long as crewmembers feel that use of the head-up display is not important, this technology will never be utilized to the fullest capacity available (Alba, 2000, p. 6). The lack of use during routine operations could also hinder the safety advantage in emergency situations because of the restrictive practice of the head-up display (Alba, 2000, p. 6). Situational awareness takes practice to master, and it is abnormal for a crewmember to divide attention between the outside world and the head-up display (Alba, 2000, p. 6). This divided attention can only be mastered through practice and training (Alba, 2000, p. 5). Cockpit resource management (CRM) training can help change the personality, attitude, and behavior of crewmembers that do not utilize the head-up display to the fullest capacity available, but in most cases it cannot change the personality traits of individuals (Hawkins, 2000, p. 183). Cockpit resource management however, is not only for the management and utilization of equipment like the head-up display (Hawkins, 2000, p. 332).

Cockpit resource management can also help with the crewmember coordination mentioned earlier because this management deals with the management and utilization of people and information available to the aircraft (Hawkins, 2000, p. 332). Cockpit resource management elements focus on " leadership, communication, task distribution, setting of priorities, monitoring of information sources, and individual performance and extraction and utilization of data" (Hawkins, 2000, p. 333).

In conclusion, the head-up display has evolved from simple iron rings used in World War II for gun sights to a modern miniature instrument panel that displays essential flight information (Ellis, 2000, p. 1). The evolution of the head-up display shows how technological processes, economics, and safety can all interact with each other effectively to create a safer approach to flying (Hawkins, 2000, p. 252). The head-up display brings many advantages and shortfalls to the crewmembers and to the aircraft. The primary objective of using the head-up display is to provide an improved situational awareness on instrument approach transitions from head-down flying to head-up flying during lower visibility flights (Hawkins, 2000, P. 252). But the head-up display has also proven to have safety advantages if used during " take-off, climb, cruise, good visibility approaches, automatic landing monitoring, roll-out guidance and wind shear protection" (Hawkins, 2000, p. 253). Both the ALPA and the Airline industry have pursued the development of the head-up display because of the advantages it offers, but the pursuit by each is for different reasons (Hawkins, 2000, p. 254).

Shortfalls such as cost, size, attentional tunneling, expectation, data clutter, disrupted visibility, and crewmember acceptance have been identified related to using the head-up display. However, the safety aspect of the head-up display by far outweighs the shortfalls it may bring to the crewmembers and the aircraft. Most of the shortfalls associated with the head-up display can be eliminated with proper training of crewmembers. Cockpit resource management training techniques can help change the personality, attitude, and behavior of crewmembers that do not believe in or utilize the head-up display (Hawkins, 2000, p. 183). Cockpit resource management can also eliminate the typical problem of ergonomics, “ Least needed equipment generate lower pilot tolerance to design imperfection then badly needed ones,” (Alba, 2000, p. 5). Through education, the crewmembers will begin to realize that the head-up display is a much-needed piece of equipment, and it is the safest approach to flying.

Bibliography

Alba, P., Audrezet, H., Aymeric, & Leger. (1999, October). Human Factor Issues Associated

with HUD-Based Hybrid Landing Systems: SEXTANT’s Experience. SAE

Technical Paper Series, 1999-01-5512, Pennsylvania: Society of Automotive Engineers.

Available: http://www. sae. org/.

Ellis, D. R., Greeley, K. W., Newman, R. L., & Schwartz, R. J. (2000, May). A Head-Up

Display for General Aviation. SAE Technical Paper Series, 2000-01-1697, Pennsylvania:

Society of Automotive Engineers. Available: http://www. sae. org/.

Fadden, S., Ververs, P., & Wickens, C. D. (2000, October). Costs and Benefits of Head up

Displays: An Attention Perspective and a Meta Analysis. SAE Technical Paper Series,

2000-01-5542, Pennsylvania: Society of Automotive Engineers. Available:

http://www. sae. org/.

Hawkins, F. H. (2000). Human Factors in Flight (2nd ed.). Vermont: Ashgate Publishing

Company.