Foundation explores effectiveness of head-up guidance system technology in accident prevention.

More than a third of nearly 1,000 recent transport category airplane accidents might have been prevented by head-up guidance system technology (HGST), according to a special report released in November 2009 by Flight Safety Foundation (FSF).[1] Moreover, the accident-prevention potential of HGST — largely due to the flight path and airspeed control guidance it provides — is significantly higher in occurrences in which the flight crew is directly involved, such as in takeoff and landing accidents, and loss-of-control accidents, the report said.

The report is based on a study conducted by Foundation Fellows Robert Vandel, retired FSF executive vice president, and Earl F. Weener, retired Boeing Commercial Airplanes chief engineer and now a presidential nominee as a member of the U.S. National Transportation Safety Board (NTSB).

The study was a follow-up to an initial study conducted by the Foundation in 1990. That study focused on civil jet transport accidents that occurred between 1959 and 1989, and concluded that HGST likely could have prevented 31 percent of them.[2]

At the time, HGST — wide-field-of-view head-up guidance systems (HGSs), also called head-up displays (HUDs), that are designed to present critical flight information to pilots during all phases of flight — was just beginning to be assimilated in civil aviation. Since the 1990 study was conducted, the civil aviation fleet has changed significantly, HGST has evolved with major technological advances, and the installation of HUDs in airline and corporate airplanes has increased considerably.

"First- and second-generation large commercial jet transports have generally been replaced by airplanes with glass cockpits and avionics systems based on digital technology," the 2009 report said. "Corporate airplanes have also undergone the change to digital avionics and electronic flight displays."

Discussing the report at the FSF Corporate Aviation Safety Seminar in Tucson, Arizona, U.S., in May, Vandel noted that the Foundation was asked by industry to take another look at HGST to determine if the levels of accident-prevention potential found in 1990 are still valid.

Expanding the Focus

Data for the 2009 study were derived mainly from the Airclaims/Ascend

Safety at EYE LEVEL

BY MARK LACAGNINA

World Aircraft Accident Summary database, the FSF Approach and Landing Accident Reduction database and the FSF Runway Safety Initiative database. The data were supplemented with information from other sources, including NTSB and other national aviation accident investigation agencies.

Expanding the focus beyond the large jet transport accidents examined 20 years ago, Vandel and Weener combed through data on nearly 10,000 accidents and selected 983 accidents from 1995 through 2007 that involved multiengine turbine and turboprop airplanes with maximum gross takeoff weights of 12,500 lb/5,700 kg or more. The airplanes included Western-built and Eastern-built models that, with few exceptions, have entered service since 1980. Excluded from the study were accidents involving military and special-use airplanes, and ground accidents involving civil airplanes.

Each of the 983 accidents was analyzed to determine whether it might have been prevented by HGST, and an independent audit of one in 10 of the accidents was conducted to confirm the analysis standards. "The goal was to gather enough relevant information about each accident to ensure the HGST assessment was as accurate as possible," the report said. The hypothetical scenario used for the assessment assumed a modern, operational HGS installed at the pilot flying's station and thorough training of the pilot flying and pilot monitoring on how to use the HGS.

The report said that the analysis of each accident resulted in one of the following five determinations:

- "Yes — It is *highly likely* that HGST might have prevented the accident;
- "Yes (?) — It is *likely* that HGST might have prevented the accident;
- "No (?) — It is *unlikely* that HGST might have prevented the accident, but information is inadequate to determine [this] with further certainty;
- "No — It is *highly unlikely* that HGST might have prevented the accident; [or,]
- "*Unknown* — Insufficient information is available to reach a reasonable conclusion about the influence that HGST might have had in the accident."

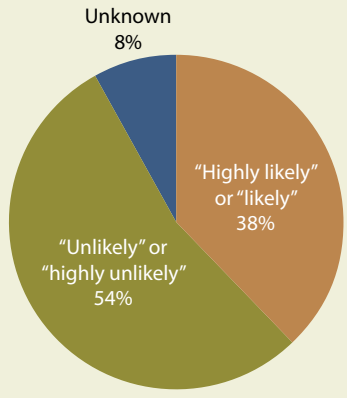
The analyses resulted in determinations that it is highly likely or likely that HGST might have prevented 38 percent (374) of the 983 accidents that occurred during the 13-year period (Figure 1). "Some 54 percent [530 of the accidents] would not have been influenced by the technology, and 8 percent [79 accidents] did not have adequate data to make an assessment," the report said.

Breakdown by Category

To refine the HGST accident-prevention assessment, the 983 accidents were grouped into nine separate categories based on the phase of flight or the primary causal factors. The assigned categories were: "takeoff and landing," "loss of control," "miscellaneous," "propulsion," "undercarriage," "environment," "collision," "explosion and fire," and "mechanical failure."

The results of the analyses of accidents in the categories in which HGST was found to have the greatest potential effect are shown in Table 1 (p. 40). "Of those accidents where the pilot was directly involved, such as takeoff and landing [accidents] and loss-of-control accidents, the likelihood of accident prevention due to HGST safety

Potential Accident-Prevention Effectiveness of HGST



983 Transport Category Airplane Accidents, 1995–2007

HGST = head-up guidance system technology
Source: Flight Safety Foundation

Figure 1

Top Three Accident Categories

Accident Category	Number of Accidents	Accidents Likely Prevented by HGST
Takeoff and landing	341	237 (69%)
Loss of control	123	70 (57%)
Miscellaneous	110	37 (33%)

HGST = head-up guidance system technology

Source: Flight Safety Foundation

Table 1

properties becomes much greater," the report said. Nearly one-half of the 983 accidents were in the takeoff-and-landing, and loss-of-control categories.

Landing accidents far outnumbered takeoff accidents, accounting for 80 percent of the total in this category. The study showed that HGST might have prevented 237, or more than two-thirds, of the 341 accidents in the takeoff-and-landing category. "In only a quarter of the accidents was HGST unlikely to have positively influenced the outcome," the report said.

The report said that HGST might have prevented 70, or more than half, of the 123 accidents involving loss of control.

Of the 983 accidents studied, 110 were categorized as "miscellaneous" because they did not precisely fit any of the other, distinct categories. For example, one accident in the miscellaneous category involved a flight crew that manually depressurized the aircraft after a windshield cracked during cruise flight. Despite donning their oxygen masks, they temporarily lost consciousness. The airplane went into a steep dive, and aerodynamic overload caused portions of the horizontal stabilizer and elevators to separate from the airplane. After regaining consciousness at a lower altitude, the crew recovered from the dive, diverted the flight and landed the airplane without further incident.

The study determined that 37, or one-third, of the 110 accidents in the miscellaneous category likely would have been prevented by HGST.

The "propulsion" category comprised 48 accidents involving engine failures or malfunctions. The study determined that HGST might have prevented or positively influenced the outcome of nine, or 19 percent, of them.

"Accidents resulting from problems with the undercarriage comprised a relatively large set of accidents, although the portion that would [likely have been positively] affected by HGST safety properties is relatively small," the report said. The conclusion was that only five, or 2 percent, of the 207 accidents in the undercarriage category might have been prevented by HGST.

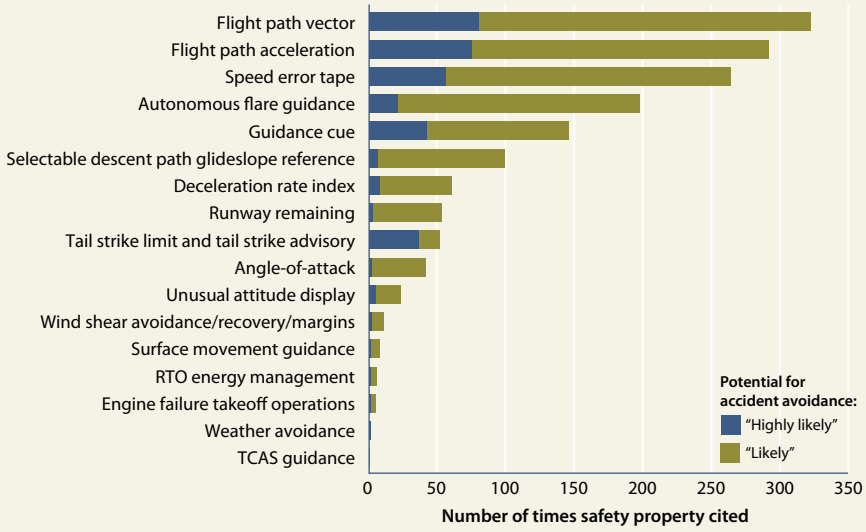
The potential influence of HGST in preventing accidents in the remaining categories — environment (50 accidents), collision (19 accidents), explosion and fire (19 accidents) and mechanical failure (17 accidents) — was found to be low. "In aggregate, these four categories comprised [about] 10 percent of the accidents in the study database," the report said. "In general, these accidents were caused by events or situations out of the pilot's direct control, and it is unlikely they might have been influenced by HGST."

Safety Properties Examined

Drilling further down into the data, the study analyzed the potential accident-prevention effectiveness of 17 individual HGST safety properties — that is, HGS/HUD display features and modes (Figure 2).

The safety properties judged to have the highest potential for preventing takeoff and landing accidents were the flight path vector, flight path acceleration cue, speed error tape and autonomous flare guidance.

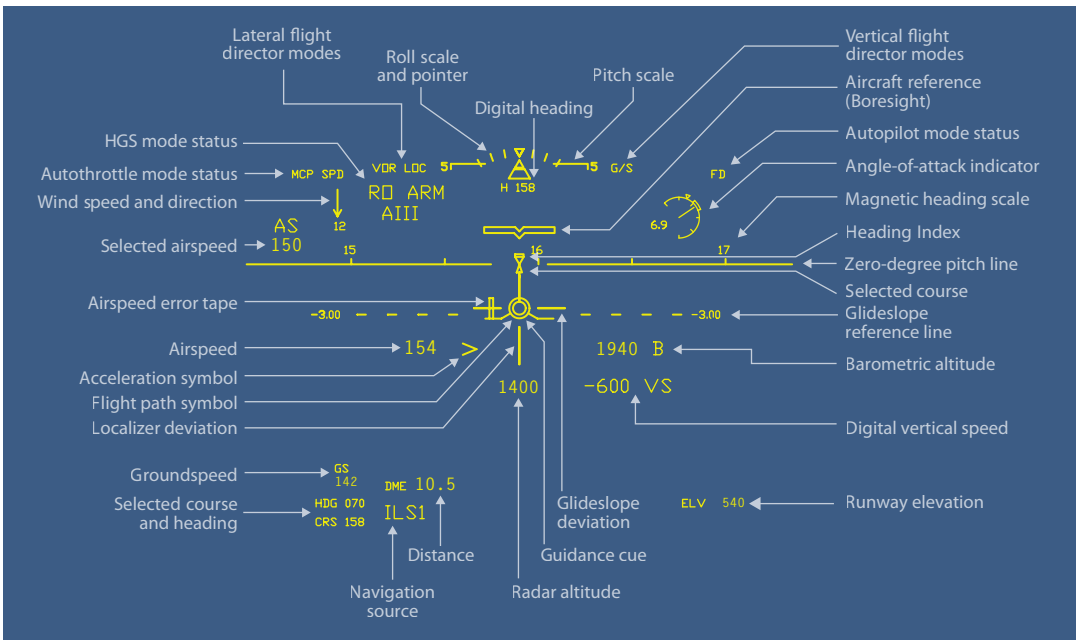
HGST Safety Properties



HGST = head-up guidance system technology; RTO = rejected takeoff; TCAS = traffic-alert and collision avoidance system

Source: Flight Safety Foundation

Figure 2



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This is typical of the information that can be provided — at eye level — on the see-through HGS 'combiner' during approach.

The *flight path vector* "provides instantaneous indication of where the aircraft is going," the report said. The *flight path acceleration cue* indicates the acceleration or deceleration of the aircraft along the flight path. The *speed error tape* indicates deviation from the selected airspeed.

Autonomous flare guidance, which is presented when the airplane is about 100 ft above ground level, "would have positively influenced almost half of the accidents in this category," the report said.

Another safety property, the *selectable descent path glideslope reference*, also was found to be a potentially important tool in preventing landing accidents. Based on the glide path value selected by the flight crew, this feature guides the crew in initiating and flying a constant-descent-angle approach. "In many of the accidents, a precision approach was not flown," the report said. "In those cases, the selected descent path glideslope symbology [would have] presented the means to increase the precision of a nonprecision approach."

The flight path vector, flight path acceleration cue and speed error tape also were judged to have the greatest potential among safety properties for preventing loss-of-control accidents. Because the incidence of tail strikes was relatively high in this category, the *tail strike limit* and *tail strike advisory* feature also was deemed an effective tool. The tail strike limit symbol appears on takeoff if the airplane is being rotated at a rate or to an extent that a tail strike could occur. On landing, the tail strike advisory appears if the airplane is in an attitude or is being flared at a rate that could cause a tail strike.

"In many cases, the unusual attitude symbology would have come into play, as well," the report said. The *unusual attitude display* appears automatically to aid in recognition of, and recovery from, an unusual attitude. The display consists primarily of a large attitude indicator with distinct sky and ground indications, and with the basic airspeed and altitude scales; extraneous information is temporarily deleted to "declutter" the HGS/HUD, allowing the pilot flying to focus on the guidance for recovering from the unusual attitude.

The report concluded that "the HGST safety properties were found to be most effective in those areas where the pilot was directly involved," such as the situations leading to the takeoff and landing accidents, and loss-of-control accidents, and many others that were categorized as miscellaneous. "Focusing on these three areas specifically, HGST [might have prevented] 59 percent of the accidents in the combination of these three categories," the report said.

Notes

1. FSF. *Special Report: Head-Up Guidance System Technology — A Clear Path to Increasing Flight Safety*. November 2009. The full report is available at <flightsafety.org/archives-and-resources/special-reports>.

2. The results of the 1990 study were published in "Head-up Guidance System Technology (HGST) — A Powerful Tool for Accident Prevention." *Flight Safety Digest* Volume 10 (September 1991).