Head-Up Guidance System™ (HGS) for midsize and light business aircraft

HGS-3500 white paper

Presented by
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Rockwell Collins
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Introduction

This paper describes the benefits and features of the HGS-3500 Head-Up Guidance System™ (HGS) from Rockwell Collins that is specifically designed to be installed in aircraft with the flight deck space envelopes typically found in the light and mid-size business jet market.
The HGS-3500 delivers many of the same features and benefits provided to pilots of large corporate aircraft such as those from Bombardier, Dassault, Gulfstream and HUDs installed in air transport aircraft such as the Boeing 737 and 787 and Embraer EJets.

The HGS-3500 includes an innovative, compact optical design contained within a single pilot display unit precisely installed in the area of the windshield sill beam. This unit provides the pilot with HUD symbology that accurately overlays the outside world and is focused at optical infinity, eliminating the need for the pilot to refocus between that HUD symbology and real world features viewed through the HUD.

Expanding the HUD market – safety directed

The Head-up Display (HUD) has been available on large aircraft for many years where it is standard equipment or a popular option. The HUD has proven itself as a valuable addition to the flight deck providing many safety and operational benefits.

Flight Safety Foundation finds the HUD is an important safety tool

In 2009, an independent Flight Safety Foundation study concluded that Head-up Guidance System Technology would likely have positively influenced the outcome of hundreds of accidents included in a study of turbine-powered, modern glass cockpit aircraft accidents. According to a presentation delivered at the 55th Annual Flight Safety Foundation and National Business Aviation Association Corporate Aviation Safety Seminar in 2010, Head-up Guidance System Technology:

- "Makes energy management intuitive"
- "Assists in avoiding traps which result in approach and landing accidents"
- "Enables you to be the pilot you always thought you were"

Bob Vandel, *Flight Safety Foundation Fellow*

The study found that 38 percent of all accidents were likely or highly likely to have been prevented if the pilot had a HUD. The study also came to the conclusion that a staggering 69 percent of landing and takeoff accidents and 57 percent of loss of control could have been avoided if the pilot had access to the information available on a HUD (a copy of this study is available at www.flightsafety.org).

Flight Safety Foundation study results

FLIGHT SAFETY FOUNDATION independent • impartial • international	Accident Category	Accidents likely positively affected by Head-Up Guidance System Technology
	Takeoff and landing	69% likely positively affected
	Loss-of-control	57% likely positively affected

HUD benefits

The Flight Safety Foundation Study details a number of HUD features that enhance the pilot's level of aircraft situational awareness, and thereby improve the overall safety of certain aircraft operations. These HUD related features which ultimately impact safety include:

- Directing the pilot's eyes outside the aircraft instead of down, while still providing all the information needed to fly the aircraft
- Providing conformal attitude and flight path information for improved situational awareness
- Intuitively displaying speed and energy information
- Displaying special symbology that will help the pilot recognize and react to nonnormal flight situations

Improved situational awareness

With better situational awareness pilots can "stay ahead of the aircraft." By having a better understanding of the interaction of thrust, lift and drag the pilot can quickly stabilize the aircraft on path and recognize when the aircraft is reacting in an abnormal way or is close to the edge of the performance envelope.

Flight path flying

The HUD is designed to provide all of the primary flight information that is available on a head-down primary flight Display. However, the most important innovation that the HUD brings to the modern flight deck is the conformal display of the aircraft flight path and introducing the concept of flight path flying.

The flight path information on the HUD is earth referenced and therefore indicates where the aircraft is actually going rather than where the aircraft airframe is pointing. Modern aircraft sensors are able to provide these earth referenced parameters in addition to the aircraft referenced parameters such as pitch and roll.

The pilot controls the flight path of the aircraft by "flying" the HUD's flight path symbol to the desired point in reference to the real world view. Therefore, flight path flying automatically reflects the effects of cross winds, angle of attack, drag, thrust and other factors which impact the dynamic state of the aircraft. This has proven especially useful to the pilot in recognizing and controlling the vertical path of the aircraft.

Figure 1: The HUD displays both conventional flight information and HUD-specific conformal symbols

With the aircraft flight path displayed, the pilot can visually evaluate and monitor the state of the aircraft. For example:

- If the flight path symbol (FPS) is on the zero pitch "horizon" line then the aircraft is holding altitude.
- If the FPS is below the line on the three degree reference line as shown in Figure 4, then the aircraft is on the glide path even though the boresight (the bar with a v shaped notch in it) shows the nose of the aircraft is pitched up above the horizon.
- In a cross wind situation the pilot can concentrate on keeping the FPS on the runway even if the aircraft is pointing to the left or right.
- In cruise, the pilot can use the FPS to confirm the aircraft will miss the thunderstorm.

A pilot currently has to mentally estimate the flight path of the aircraft during an approach; so conformally displaying the information on a head-up display significantly reduces the pilot's workload. Pilots welcome this additional information and require very little additional training to be proficient at flight path flying.

Aircraft control

Other HUD symbols intended to assist in the task of controlling the aircraft's flight path are referenced to the flight path symbol. The flight director cue is a circular symbol that fits within the flight path symbol – to stay on path the pilot maneuvers the aircraft so the "large circle is over the small circle" as shown in the examples of Figure 2.

Figure 2: The HUD guidance cue is easy to follow

Even if the pilot is using the Flight Management System to guide the aircraft, many pilots use the HUD symbology to monitor the aircraft path – especially in the terminal area. The pilot can continue to see flight information and keep his/her eyes outside the aircraft. This is particularly important during an approach where the position of the flight path symbol and the appearance of the runway symbol eases the transition from instruments to visual sighting and aligning with the runway. With a HUD the pilot can be head-up throughout the approach avoiding the difficult head-down to head-up transition prior to decision height.

As an extension of the flight director cue, the HUD has a special algorithm that calculates the optimum flare maneuver intended to ensure a smooth landing on the runway. This algorithm utilizes descent rate and the radio altimeter information to guide the pilot through this stressful maneuver even at steeper than normal approach path angles. This feature is especially useful when flying to unfamiliar runways which may be sloped or during nighttime approach and landings.

Energy management

Energy information is also referenced to the flight path symbol with speed error shown as a variable length tape on the flight path symbol leg and acceleration/deceleration represented as a caret. This combination (see Figure 3) makes staying at the target speed easy and intuitive.

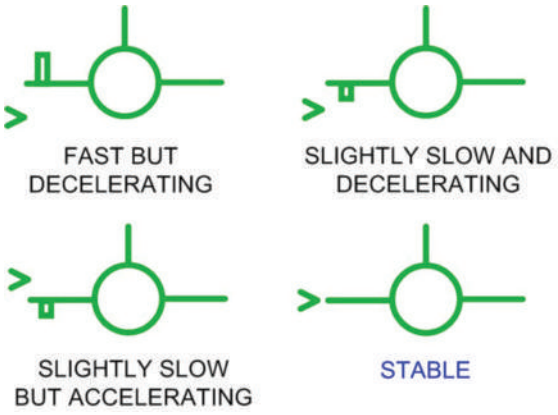


Figure 3: Speed control is easy with the HUD

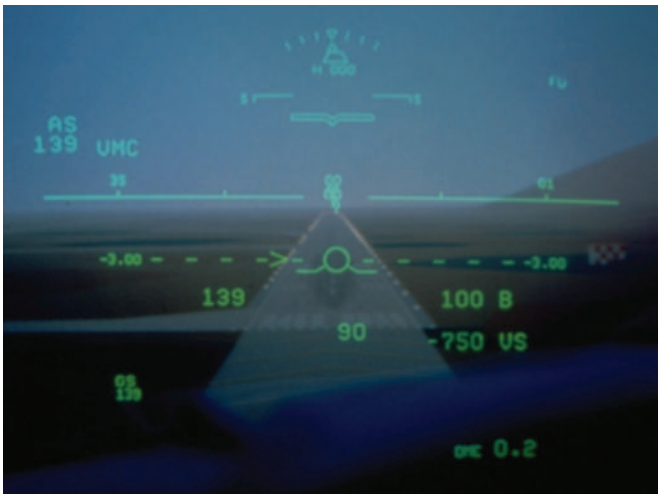
This combination of path and speed awareness makes the task of establishing and maintaining a stabilized approach a quick and easy set-up even with a cross wind and turbulent conditions.

During the landing rollout, a readout of the remaining runway helps the pilot optimize breaking and a braking effectiveness scale helps the pilot confirm that brakes are slowing the aircraft down as expected.

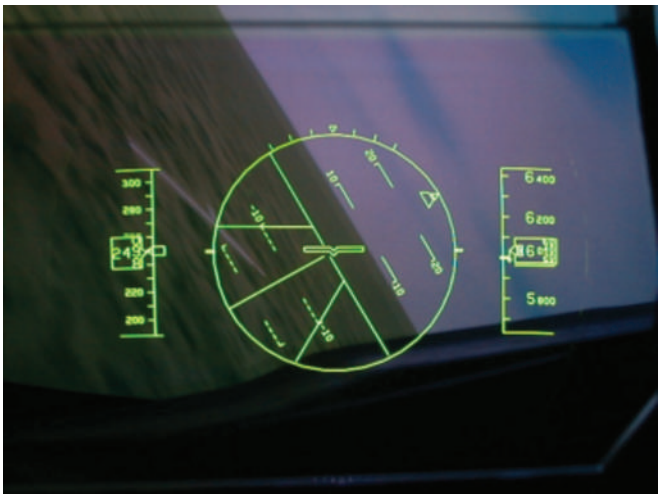
Non-normal situation response

The flight path symbol and other information on the HUD also helps the pilot to both recognize and recover from several non-normal situations, such as:

- Windshear – Sudden changes in wind speed or direction are instantly recognized when the pilot is monitoring the aircraft flight path acceleration. A sudden rise or drop in the flight path acceleration caret is a signal that the aircraft could be entering a dangerous situation and the pilot should abandon the approach and potentially apply full power while traversing the windshear region.
- TCAS alerts – The HUD presents a TCAS climb or descend command as either a fly-to box or a keep-out region. The pilot maneuvers the aircraft so the flight path symbol remains in the safe traffic avoiding region.
- Unusual attitude – If the aircraft enters an unusual attitude with larger than normal pitch or roll, the symbology on the HUD changes to a simplified mode that alerts the pilot to the situation and helps the pilot recover to a normal attitude.



The flight path symbol makes flying a visual approach easy – even in a cross wind



Unusual attitude symbology helps you recover quickly after an upset

Figure 4: The HUD Includes special symbology for many situations

Further support of visual operations

The synthetic vision view, displayed conformally on the HUD, helps the pilot maintain situational awareness by supplementing the outside world view. A powerful graphics processor generates the synthetic vision image using information selected from a worldwide terrain database based on the aircraft's current position and orientation.

This allows the generated image to accurately match the pilot's actual view through the HUD. This synthetic vision image is available in all weather conditions and includes the obstacle and runway information also included in the database information.

The HUD can also display an Enhanced Vision image from an infrared camera if one is installed on the aircraft.

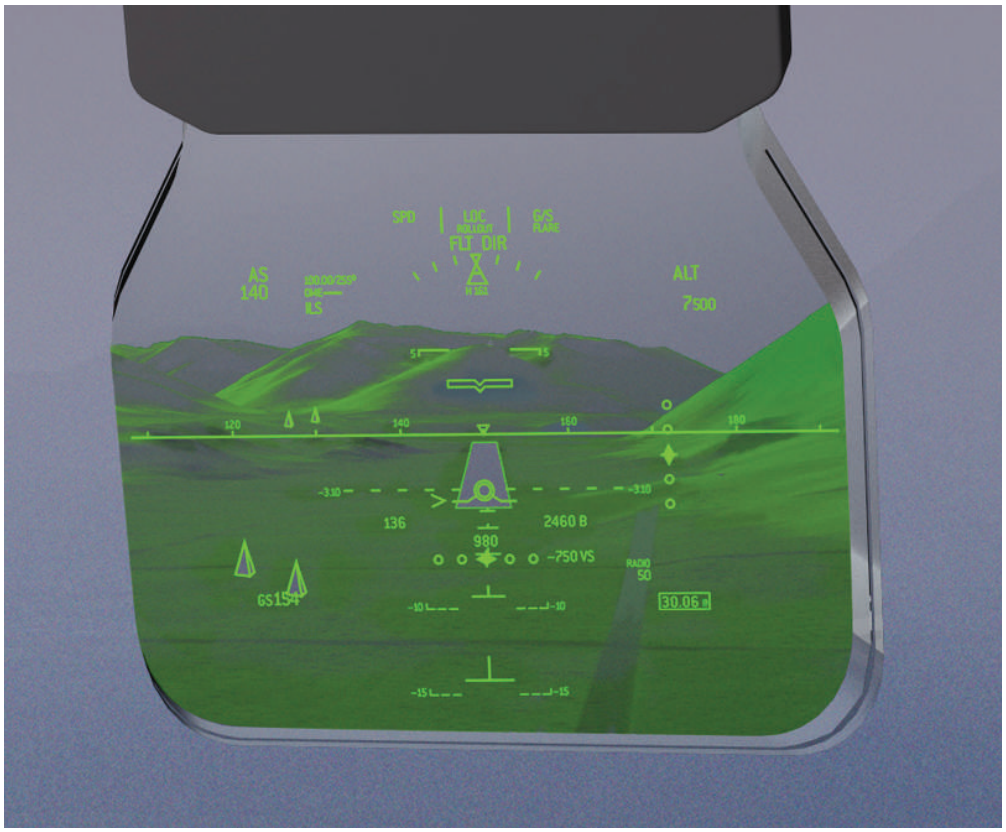


Figure 5: Conformal synthetic vision on a HUD

HUD benefits now available to small aircraft

It has always been a Rockwell Collins goal to provide the benefits of a HUD to all classes of aircraft. With the HGS-3500, Rockwell Collins is achieving breakthrough performance in several key areas which enable realization of this goal:

- Space – It has been a challenge to fit a conventional HUD from a large aircraft into smaller aircraft due to the limited amount of room above the pilot's head where the projection unit is usually installed.
- Cost – Large aircraft HUDs are custom designed to fit each aircraft type and use expensive relay optics to project the HUD image to the pilot. This made a conventional HUD exceed the budgets of small aircraft owners.
- Sensors – To present flight path information to the pilot the HUD would typically need upgraded aircraft sensors, but new high accuracy sensors will be available for the mid size and light aircraft market segments that are compact and affordable.

Rockwell Collins HGS-3500

The Rockwell Collins HGS-3500 will be available to bring the benefits of the head-up flight path flying with synthetic vision to midsize and light business aircraft. The HGS-3500 uses innovative, compact optics to minimize the size and cost of the HUD while retaining the important features that make the HUD an important aircraft safety and operations tool:

- Collimated image – the pilot's eyes see the HUD image when focused on the outside scene
- Conformal symbology – the HUD is accurately aligned to the aircraft so symbols such as the flight path symbol accurately overlay the outside world
- High brightness – bright enough to see even when viewed against a sunlit cloud
- Wide field of view – see the flight path symbology even when a cross wind causes the aircraft to crab during an approach
- Full flight symbology – all the information the pilot needs to fly the aircraft

Innovative Optics

The optical configuration used in the HGS-3500 is called an optical waveguide. This innovative concept uses a flat plate of glass acting as a waveguide that is positioned in front of the pilot. Diffraction gratings bend the light from an LED-illuminated liquid crystal microdisplay into and out of the waveguide, sending the image into the pilot's forward field of view. These transparent gratings allow the pilot to see an expanded view of the HUD image provided by the microdisplay - collimated and overlaid on the outside world.

Figure 6: The HGS-3500 Display Unit is installed above the windscreen.

HGS-3500 characteristics and performance

The following table presents the characteristics and performance measures of the HGS-3500.

Characteristic	Description/Performance
Cockpit fit	• Clears primary structure of light business jets • Meets HIC requirements defined in CFR 14 25.562 Emergency Landing Dynamic Conditions (Head Injury Criteria subparagraph) • No Upper Clear Vision obstruction when combiner is deployed or stowed
Head motion box	• Meets SAE AS8055 requirements • >15 degrees of horizontal field-of-view with a head motion of +/-2.75" from cockpit design eye point. • Vertical eyebox is >3.0"
Safety/HIC	• Primary flight reference integrity • Moves out of pilot's head path during HIC event (16g crash safety deceleration)
Display quality	• Highly corrected optical system provides sharp display characters
Eye relief	• > 6" in light business jets
Aesthetics	• Chassis is blended within cockpit trim panels • No impact to cockpit vision polar when combiner is stowed
Number of LRUs	• Pilot display unit is a single LRU each vs. 2-3 for a conventional HUD

Flight deck integration

The HGS-3500 is an integrated part of the Rockwell Collins Pro Line Fusion™ flight deck with common symbology and an integrated user interface. The HUD shares hardware resources with the Head-down Displays saving size, weight and power and ensuring that this important safety system is an affordable addition to the flight deck.

The HGS-3500 includes pilot controls that allow the symbology and video image to be adjusted independently. A forward looking ambient light sensor adjusts the image brightness automatically as the background scene brightness changes.

Summary

Owners of midsize and light business aircraft will now have the safety benefits of the Head-up Display available in their aircraft including head-up flying using a conformal flight path symbol, more stabilized approaches and conformal display of synthetic and Enhanced vision. Until now there has not been a high performance conformal HGS available that would fit in an midsize or light business aircraft flight deck space envelope. With the HGS-3500 from Rockwell Collins, more pilots will benefit from improved situational awareness, reduced workload and an improved level of safety.

Building trust every day.

Rockwell Collins delivers smart communication and aviation electronic solutions to customers worldwide. Backed by a global network of service and support, we stand committed to putting technology and practical innovation to work for you whenever and wherever you need us. In this way, working together, we build trust. Every day.

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