HANDS ON: HUD AND FLY-BY-WIRE ENHANCES LEGACY 500

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The first OEM customer for the Rockwell Collins HGS-3500 compact head-up display (**HUD**) is Embraer, which selected the new HUD for the **Legacy** 450 and **500** midsize jets. The HUD is optional, as is the Rockwell CollinsEVS-3000 enhanced vision system, and they can be installed either individually or together.

The best installation is the combination of the HGS-3500 HUD and EVS-3000 because then the operator realizes the full benefits of having a HUD, in this case the ability to play both EVS (mostly infrared) and synthetic vision system (SVS) imagery on the head-down primary flight display (PFD) and multifunction display (MFD) and theHUD. The combined system is branded as E2VS, and it allows pilots flying smaller aircraft to derive the benefits–and pleasure–of flying with a full enhanced flight vision system (EFVS), just like the far more expensive and larger Falcons, Globals and Gulfstreams.

What makes the compact HGS-3500 stand out is that it is a singular unit, mountable in front of the pilot and without the need for a bulky projector taking up space and adding weight on the cockpit ceiling. In addition to being smaller and lighter, the HGS-3500 is much less expensive. On the Legacy 450/500, the HUD adds $275,000 to the jet's price. The EVS-3000 is another $275,000 by itself. But combined, a buyer can whittle the total for the E2VS down to $500,000, roughly half the cost for a full-size EFVS in a large-cabin jet. The E2VSinstallation in the Legacy 450/500 weighs less than 40 pounds, versus 77 pounds for traditional EFVS.

To make the move to HUD/EVS in the new Legacys, Embraer is offering buyers the option to hold

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off on buying the units, while paying for provisioning of the wiring and brackets that will be needed to add E2VS later. This will make their airplane more valuable on the resale market and also encourage buyers to take the HUD/EVS plunge sooner rather than later, which is an interesting strategy on Embraer's part and also indicates how strongly Embraer believes in HUD/EVS. Embraer is also developing a service bulletin to retrofit non-provisioned Legacy 450s and 500s.

The HUD and EVS systems will be available starting in the middle of next year, according to Alvadi Serpa, head of product strategy for Embraer. "Some customers are already asking for it. We're experiencing a higher take rate than we initially expected."

FLIGHT TEST 500

AIN traveled to Embraer's headquarters in São José dos Campos, Brazil, in September to try out the newHUD/EVS in a prototype Legacy 500. From the outside, the EVS-3000 cameras live inside an aerodynamic blister mounted on top of the nose, which doesn't interfere with the airflow or elevate the cockpit's low noise levels. There are three cameras inside the blister: two are infrared sensors and non-cooled, which means they are not quite as sensitive as the more expensive cooled EVSs found in larger jets. The two cameras cover separate portions of the infrared spectrum–one shortwave and one longwave–and they are both protected by a single sapphire lens on the left side (looking at the nose from in front of the airplane).

The right side of the blister houses a natural-light camera protected by a normal glass lens. This camera is there primarily to allow the system to detect and display LED lights, which are poised to become more widely used for runway and airport lighting. The infrared cameras detect heat, and LED lights are undetectable unless equipped with some kind of heat-emitting element.

Rockwell Collins engineers devised a way to merge the inputs from the three sensors (two infrared, one natural light) to create the image on the PFD, MFD or HUD. As an enhanced flight vision system, the HUD/EVS also has the added benefit of allowing pilots to descend a further 100 feet on a Cat 1 ILS approach, making the Legacy 450/500 more flexible in inclement weather. As Rockwell Collins describes it, "The process of merging or 'fusing' the three images is performed by the video merge function and requires that each image be properly scaled and formatted before, or as part of, the video merge function. For the three images to overlay each other properly, the detector cores are precisely aligned with respect to the EVS-3000 chassis. The merged/fused image output can then be further scaled and positioned by the HUD for the image to precisely overlay the real world scene as viewed through the HUD." To present the best image to the pilot, the algorithm that governs the merging of the three images prioritizes the point source–that is, whichever camera is primarily supplying the imagery.

In practice, what the pilot sees using E2VS during an approach at an airport with lights turned up to a bright setting will initially be the lights, but then the surrounding terrain and runway become more prominent as the algorithm balances the input from the three sensors. The lights will thus become less prominent so the pilot can see the runway and terrain better.

COCKPIT INSTALLATION

Inside the cockpit, the compact HUD's pilot display unit (PDU) replaces the separate and bulkier projector and combiner lens of a traditional HUD (most modern business jets with HUDs are equipped with a Rockwell Collins 6000-series unit). A big difference between the compact HUD and the 6000-series is the eye relief or distance from the combiner lens, about six inches for the

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compact HUD and 9.5 inches for larger HUDs. The compact HUDalso has a slightly smaller field of view. “Once you sit there for the first time, you see it’s closer than other HUDs you’ve flown before,” said Embraer chief test pilot Eduardo Camelier. “In minutes you forget about it. Because it’s closer, even though smaller, it feels like you don’t lose anything even with the smaller field of view.”

A regulatory requirement is that the combiner for a larger HUD or the compact HUD’s PDU be stowable using one hand. For the HGS-3500, the pilot pushes a button on the side of a bracket, and the HUD swivels 180 degrees to where it can be clicked into a solid retainer. Pushing the same button releases it from the retainer, then it swivels and locks back into position. There is no adjustment of the HUD for the pilot; once it is installed, that is its permanent position, and the pilot has to position his or her seat correctly to provide the optimum view through theHUD lens.

Two knobs on the HUD allow the pilot to adjust image brightness and contrast. The pilot can select three HUDmodes on the Rockwell Collins Pro Line Fusion avionics: automatic, declutter or full, but most will find it easier to remain in the automatic mode, which adjusts the amount of information displayed depending on the flight phase. The flight-path vector can be caged, too, and a button on the flight guidance panel selects the video overlay for the HUD, either off, SVS or EVS. Eventually this button (currently marked CVS for combined vision) will allow selection of combined vision, which is a fusing of the SVS and EVS imagery, but that will depend on how soon regulators allow lower landing minimums for CVS. The pilot also has a video kill switch on the lower rear right side of the sidestick, and this toggles whatever image (EVS or SVS) is on the HUD on or off, allowing the pilot to remove the image rapidly for a clear view through the HUD.

On the 15.1-inch Pro Line Fusion displays, EVS can be displayed in a quarter window, alongside SVS on the PFD. The copilot can run the same quarter-window EVS display, too, as well as SVS on the right-side PFD, or the EVSimage can run on the two MFDs.

FLYING THE 500 HUD

After briefing for the planned night flight in a flight-test Legacy 500 that was still full of test equipment, at Embraer’s headquarters at São José dos Campos Airport, I climbed into the left seat and adjusted the seat to set up the view through the compact HUD. Unlike a cooled EVS, which takes minutes to calibrate, the Legacy’s EVSpowers up and auto-calibrates right away. We were parked in front of an Embraer hangar and could see the heat signatures of ground personnel walking in front of the Legacy and inside the hangar.

When I adjusted the seat height and position so that I could see the entire picture on the HUD, it felt initially as though I was sitting a little farther forward than the last time I flew the Legacy 500. But this might have been because at first it felt a little strange for my face to be so close to the HUD. I have flown with the larger HUD in a Global 6000, and there is a definite difference between the two systems. In any case, as soon as the ground crew pushed us back and we started the engines, my seat position felt just fine.

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Taxiing the Legacy 500 with the variable nosewheel steering using the rudder pedals provides precise control on the ground. At first I tried looking through the HUD while taxiing, but I found that the centerline was a little hard to see, although the taxiway lights were clearly visible. I occasionally looked around the edge of the HUD to see how that looked, but of course I could also have simply killed the EVS video overlay in the HUD using the button on the sidestick. At the time, I didn't think of trying the video kill switch. I could also have moved the HUD out of the way, but the purpose of this flight was to try out the HUD as much as possible, so I kept it in place.

On takeoff from Runway 15, Camelier called out the speeds and when he said "rotate," I pulled back on the sidestick and used the attitude indicator and flight path vector (FPV) depicted in the HUD to set the initial climb angle. The HUD instrumentation depictions responded just as promptly as on the PFD. The Legacy 500 fly-by-wire flight controls begin in direct mode until 65 knots, which means that the sidestick directly controls the flight control surfaces with no envelope protection. After 65 knots, the fly-by-wire system transitions into takeoff mode for three to five seconds, and this is a pitch-rate control mode that makes it easier for the pilot to set the climb angle. Normal mode then kicks in, and in this mode the pilot selects the flight path and the fly-by-wire system automatically trims and maintains that path until he selects a different path.

While this might sound complicated, it is a completely natural way to fly, and it felt even more comfortable during this flight, my second in the Legacy 500. Somewhat to my surprise, flying while looking through the HUD instantly felt comfortable.

CLOUDS AND GROUND

I hand-flew to 10,000 feet, and we never used the autopilot because the way the fly-by-wire maintains the flight path makes the autopilot feel redundant. There were clouds covering the mountains near Campos do Jordão, which is about in the center of Embraer's flight-test area, and I spent some time trying the EVS on the HUD then comparing that view to the quarter-page EVS image on the PFD.

The EVS image clearly showed the lights of Campos do Jordão through the clouds, and when I turned my head to look through the windshield, darkness was all that I could see. I found that there was a subtle difference between the green monochrome EVS image on the HUD and the black-and-white image on the PFD. The PFDimage seemed to show more definition of clouds and also of a haze layer in an area where there were no clouds. I experimented with the contrast and brightness controls and was able to obtain a satisfactory setting that better matched the HUD image to the PFD image.

I switched on the SVS on the HUD, using the Pro Line Fusion trackball to make a selection from a drop-down menu on the PFD. At first I was a little surprised at the relative brightness of the SVS image on the HUD compared to the EVS image. Camelier explained that the SVS image contains much more information, and I found it helped to turn down the HUD's brightness control when viewing SVS imagery. The SVS view through the HUD perfectly matched the SVS view on the PFD, clearly showing the mountains below and the not-too-distant shoreline. LikeSVS on the PFD, the HUD SVS includes the handy Rockwell Collins airport dome depiction to show the location of the destination airport.

We headed back to São José dos Campos and the Rnav approach to Runway 15. I kept looking through theHUD and just followed the FPV's guidance during the approach, and the Legacy 500's autothrottles kept the jet smoothly on speed and flight path. The weather at São José dos Campos

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was clear with some scattered clouds, and I had the HUD set with EVS displayed, and SVS on the PFD as well as the approach chart on the right half of the PFD.

The first landing was a touch-and-go, and as we approached the runway the airport lighting and runway were comfortably displayed on the now-decluttered HUD, with the lights not overwhelming the view of the runway. I kept looking through the HUD during the landing, and as we descended below 50 feet the autothrottles retarded power. I flared a little high, and the Legacy 500 floated a bit until I managed to position the nose properly, but it's hard to land this airplane badly with its trailing-link landing gear and the touchdown was smooth. I gave the power levers a push, and the autothrottles took over, and after takeoff I turned onto downwind for another landing. This one was a little smoother, although I realized later that I was pulling the nose up too high during the landing; Camelier explained later that holding the nose on the horizon is all that is necessary, and this is easy to do while looking through the HUD. The HUD also provides a flare cue, but I didn't use it.

After landing, having flown the entire 50-minute flight while looking through the HUD, I was much more comfortable taxiing without trying to look around the HUD. Flying with the HUD in the Legacy 500 felt surprisingly natural. The fly-wire-wire controls and the HUD and the FPV seemed perfectly matched; selecting the flight path with the sidestick makes flying much easier, but putting the flight guidance cue inside the FPV is so much more satisfying and achievable with the fly-by-wire flight controls. Just set the flight path, leave the sidestick alone, adjust if necessary, and that's it. The fly-by-wire does all the work. This is so different from flying with ordinary flight controls, where the pilot has to work all the time with endless tiny adjustments to make the airplane match the desired path. Each time I fly the Legacy fly-by-wire, it becomes more and more natural, and adding the HUDto the mix just reinforces that level of comfort.

For the relatively reasonable price of the entire E2VS or even just the HUD, it seems likely that this will be a popular option on the Legacy 450 and 500, especially after pilots get a chance to experience fly-by-wire combined with HUD firsthand.

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