



COCKPIT AVIONICS: PART 2

New rules unleash helpful HUDs

by Matt Thurber

The FAA's new rules allowing the use of enhanced flight vision systems (EFVS) instead of natural vision to descend below 100 feet above touchdown zone elevation and then land and roll out will likely lead to installation of more head-up displays (HUD) and wearable head-mounted displays in an expanding variety of aircraft types. Avionics manufacturers are ready for the rule change and preparing for the added utility offered by their HUD systems, and some are offering products that can meet the new rules' requirements for aircraft not equipped with a HUD.

ELBIT HEAD-UP DISPLAYS

A couple of thousand airplanes are equipped with Elbit's EFVS, according to Dror Yahav, v-p of the company's commercial aviation-aerospace division. "A lot of them will be able to leverage the new rules," he said, especially airlines, which should be able to take advantage of the new credits for dispatch, takeoff, approach and landing.

What makes the new rules so beneficial for operators is that they focus on the performance of the enhanced vision system (EVS) that is a key part of an EFVS. "As long as the system meets certain criteria, they will be able to enjoy the credit," he said.

Elbit's cryogenically cooled Kollsman EVS camera systems are installed on airliners and Gulfstream and Falcon business jets. Generally, the Gulfstream installations are fitted with a Rockwell Collins head-up guidance system. Dassault was the launch customer for a complete Elbit EFVS with Elbit's HUD and ClearVision camera/sensor system, and this is branded as FalconEye, available in new Falcon 2000s, 900LXs and 8Xs.

The FalconEye EFVS blends synthetic,

database-driven terrain imaging and actual thermal and low-light camera images into a single view, heightening situational awareness in poor weather and all flight conditions. FalconEye incorporates a multi-sensor camera to present images in both the visible and infrared spectrums, enabling a clear view of LED lights on airports where these are being implemented. Images are combined with three worldwide synthetic vision databases that map terrain, obstacles, navigation and airport and runway data.

While the EFVS is already available in these aircraft, Elbit is working on validation of its system to allow operators to take full credit under the new rules. The FAA has issued draft guidance on how this validation can be accomplished, and it will involve ground and flight tests to test the system's performance in varying weather conditions. Elbit expects to complete the validation by year-end.

Business airplanes being flown under FAA Part 91 regulations have always been allowed to begin an IFR approach even when the airport's weather

Dassault FalconEye



is below minimums, but airlines can't do this, constraining their operations. Under the new rules, Yahav explained, airlines will be able to dispatch and begin an approach with weather reported below minimums. So, he added, "I think the main interest [in the new EFVS rules] is coming from the airlines."

ROCKWELL COLLINS

From its founding in 1979, the former Flight Dynamics, now Rockwell Collins Head-up Guidance Systems (HGS), designed products to help keep pilots in the loop, or fully engaged in the process of flying. The company's first HUD came about because Alaska Airlines was losing money diverting to other airports when destinations were fogged in. The airline found that the new HUDs could deliver much more utility for a fraction of the price of expensive autoland systems, all while helping pilots stay in the loop.

HGS has manufactured 8,500 HUDs that have flown 60 million hours in commercial and military service. Rockwell Collins is also partnered

with Elbit Systems on the Lockheed Martin F-35 helmet-mounted display.

Now the HGS division is working on certifying its latest digital HUDs and EVS camera systems to meet the new EFVS rules. Combined vision, which fuses EVS and synthetic vision system (SVS) imagery on a single display (HUD and primary flight display) will eventually be covered by the new rules as well.

The Rockwell Collins 6000-series digital HUDs use LCDs to project the image onto the combiner display mounted in the pilot's view. Earlier HUDs are analog and use CRTs to project the image, but LCDs deliver a brighter picture. "The faster you write [the image] for video," explained Robert Wood, senior fellow HGS Commercial Systems, "the less energy is available for brightness." The digital nature of LCDs involves switching individual pixels on and off, and this allows the full brightness capability of the LCD projector to be used to draw images on the combiner. Both the analog and digital systems are termed "relay-lens" HUDs because of

the way the imagery is projected.

HGS has pushed HUD technology even further with the HGS-3500 compact HUD, which for the first time uses a waveguide instead of a projector to send the image to the combiner. The first application for the HGS-3500 is in Embraer's Legacy 450/500. The benefit of the waveguide HUD is that it takes up far less space in the cockpit and is thus adaptable to smaller aircraft with no room for a full relay-lens HUD.

Designing the waveguide HUD, said Wood, "was no small task." The project involved evaluating head-injury criteria in the cockpit and extraordinarily detailed optical engineering, for example, manipulating precise placement of diffraction grates that keep the light inside the waveguide on its way through complex turns of up to 90 degrees, then finally delivering an accurate image to the combiner.

"It's complex," Wood said. "You can't buy software to design a waveguide. We had to develop models, predict performance, then measure it, then tweak the model."

Rockwell Collins HGS's development of the compact HUD system also depended on the EVS-3000 camera, which consists of three cameras/sensors; one detects visible light, so it can "see" the LED lights that are growing in popularity at airports all over the world (they're not visible by infrared sensors). The other two cameras are a short-wave and a long-wave infrared sensor, and all three are uncooled, which simplifies the installation and makes maintenance cheaper than it is with cryogenically cooled EVS systems.

At present, Rockwell Collins HUDs don't offer combined vision, but HGS is researching this technology and preparing to offer it as a commercial product. Rockwell Collins does offer



Rockwell Collins combined vision

switchable views, between EVS (infrared) and SVS, just not both at the same time. “We’re trying to get the best view and show it to the pilot,” Wood said. “We want to filter our elements that aren’t enhancing vision. We’re close to launch for a combined vision customer, and there’s no reason it couldn’t work on both the 6000- and 3500-series [digital HUDs].”

ASTRONICS

Astronics Max-Viz is collaborating with the FAA in a research project to study operational concepts for the use of EFVS in helicopters. While EFVS rules address approaches to runways at airports, there are no comparable regulations for EFVS aboard helicopters flying to onshore or offshore helipads/heliports.

For the study, Astronics is providing Max-Viz 1500 and 2300 EVS to the FAA for installation in the agency’s Sikorsky S-76 testbed. Flight-testing is being conducted by the FAA’s William J. Hughes Technical Center at Atlantic City International Airport in New Jersey. The Max-Viz 1500 sensor will provide baseline testing, which will be followed with the installation of the Max-Viz 2300 for observation of LED lighting on the blended high-resolution long-wave infrared image. The helicopter will fly in various weather and visibility conditions, day, night and twilight and on alternative approaches. The FAA will use the results of the study to evaluate the effectiveness of EFVS technology for helicopter flight safety and operations.

GARMIN JOINS THE PARTY

Garmin unveiled its first foray into the head-up display (HUD) market in May, the new Garmin head-up display (GHD 2100), which Textron Aviation has selected for the Cessna Citation Longitude. The super-midsize Longitude has a Garmin G5000 flight deck, and the GHD 2100 was installed in the prototype Longitude (the first flight-test article).

The GHD 2100 is designed to fit into light, mid-size and super-midsize business jets and consists of a single display unit with a self-contained projection system.

Information displayed on the GHD 2100 is consistent with Garmin symbology and provides flight-critical primary flight display information and Garmin’s synthetic vision technology (SVT).

Garmin’s SurfaceWatch is integrated on the GHD 2100. It uses performance data entered into the Garmin avionics before takeoff to provide visual and aural cues to warn pilots about taking off or landing on the wrong runway or on a taxiway, or that a runway is too short.

Garmin plans to add options to the GHD 2100, such as displaying imagery from external cameras, infrared-based EVS and blended EVS and SVT to deliver a combined vision system. The company says the GHD 2100 will “target” the new EFVS rules, according to a Garmin spokeswoman.

HEAD-DOWN STILL AN OPTION?

The new EFVS rules are HUD-centric, which is good for HUD manufacturers but leaves others, for now, out of the running for credits allowing dispatch, takeoff, approach and landing in certain kinds of poor weather or below-minimums conditions. While HUDs allow pilots to view flight symbology on a combiner display mounted in the view through the windshield, so-called head-down displays (primary flight displays or PFDs) pull the pilot’s view back into the cockpit, down and away from the windshield.

“That’s a correct interpretation of what the rule says,” acknowledged Thea Feyereisen, aerospace fellow at Honeywell’s Flight Safety Systems Group in the company’s Advanced Technology research arm. “Head-down displays are precluded from [the new rules].”

But Honeywell’s human factors engineers and researchers “have done a lot of research on

Garmin GHD



head-down displays and continue to do so,” she said. At the same time, the software that Honeywell has developed to run on its PFDs is easily portable to HUDs or wearable “near-the-eye” displays. “The software is portable between different display mediums,” she explained.

There are advantages to head-down displays, chief among them their ability to handle information-rich imagery and deliver far more detailed and colorful SVS pictures than can be done on lower-resolution HUDs or wearable displays. Infrared sensors by themselves have many limitations on what they can bring to a display, especially when it comes to penetrating obscuring phenomena such as moisture-rich fog. “The big hurdle in certification is the performance of the sensor,” Feyereisen said. “If you’re using only infrared, it’s going to work only as well as the

sensor. The biggest hurdle in terms of [showing what looks like] reality is not software to show pretty pictures; it’s being able to do the picture to show what’s required.”

What this means is that combined vision delivered on a head-down display is Honeywell’s goal. And its first product is coming soon on the Gulfstream G500 and G600, a synthetic vision-based 3-D airport moving map.

The idea here is that the HUD and EFVS (which will be installed in the G500/G600) might help the pilot make it down onto the runway, but the fog might be so bad that the pilot can’t taxi. “This rule only addresses landing,” she said, “but how do you get to the gate [or FBO]? As a designer, I can do a lot more pretty pictures if more colorful pixels are available than today’s see-through display technology. We go for more of a combined

vision system, and combine infrared with database information. That's when we get the best picture for the pilot."

Honeywell has tested head-down displays extensively, with pilots in simulators and Gulfstream and Falcon jets, using combined vision to land in simulated and real weather conditions. The research found that pilots could easily land only by reference to the head-down synthetic vision display, combined with infrared imagery, and to a high degree of repeatable accuracy as documented by measurement of the touchdown location.

One aspect of the new rule puzzles Feyereisen. "It never requires you to transition to external visuals," she explained. "If the pilot doesn't need to see out the window, why are you [including] this 'look out the window' requirement? This rule enabled what pilots were doing already; they're never transitioning outside, their eyeballs were looking forward, but fixated on symbology, and never transitioning to the real world. It takes a special pilot to transfer from the imposing dominance of green stuff [on the HUD combiner] in front of your face and then to see through it."

There is a parallel in simulator training, where pilots learn to fly a jet solely by reference to a simulated environment. "[The head-down display] is an electronic representation of the external scene," she said. "Every time pilots go to Flight-Safety, it's not the real world, the visuals are electronically represented. It's a little different from flying in the real world, but they're able to complete the task with an appropriate level of safety."

The new rule is somewhat frustrating for Honeywell researchers in that it is still too focused on specifying a particular technology—HUDs—instead of a target level of safety. "It should be performance-based," Feyereisen said, "rather than specifying technology. Technology is moving so fast. When we bring in a new techno-widget, having a

performance-based requirement would be much faster and easier."

For Honeywell, a colorful head-down display offers many benefits, most important being that pilots have to spend more cognitive effort interpreting green HUD symbology compared to a head-down display with high-definition resolution and millions of colors. "There is a certain amount of interpretation for 64 shades of green [on a HUD]," she said. "People think the sky is blue and the earth is brown. There is a requirement [for pilots] for color vision. Why? So they can differentiate runways from taxiways [at night using different colored lights], so color is a big part of encoding the aviation infrastructure. Yet now they're saying that you can land and taxi and you don't need color? How are you mitigating that lack of color?"

A head-down display is generally larger than a HUD combiner. "Bigger is better in this case," she said, "because of the visual experience you can provide for the pilot."

One of Feyereisen's favorite subjects is visual systems: "Optical flow, which is this sensation of how you move through the world. If you move your head right or left, there are different visual angle points that accelerate as you move right or left, and that helps orient you as you turn. A dotted centerline, how that passes [gives you] certain speed cues and orientation cues. Having optical flow with color helps pilots with orienting, and a large display can do a lot to orient a pilot."

Ultimately, Feyereisen concluded, "Vision systems, whether they're enhanced vision, synthetic vision or combined vision, are transforming how people are flying and how people will fly. Think of that in terms of providing the pilot with a picture that's worth a thousand words. A good picture helps the pilot significantly in terms of orientation and awareness of what's happening."



WEARABLE HUDs

Elbit Systems expects to certify its SkyLens wearable “near-the-eye” (NTE) dual-display HUD in the ATR 72 in the middle of next year, according to Yahav. The advantage of the NTE HUD is not only its cost (much lower than an installed HUD) but the ability to retrofit it into many cockpits where a HUD, even a compact Rockwell Collins waveguide system, can’t be mounted.

Elbit expects full credit under the new EFVS rules for the SkyLens system when a compatible camera/sensor system is installed. In the ATR 72 application, the HUD will be worn by one pilot,

but some potential single-aisle airliner customers are asking for a dual-HUD installation, one for each pilot. “It doesn’t take lot of space,” he said. Installation time is low, taking one to two days compared with weeks for a full HUD retrofit. “The impact on the cockpit is minor. The functionality is quite significant. [Customers] will get a new enhanced, synthetic and combined vision system.”

The SkyLens NTE works with Elbit’s Clear-Vision camera/sensor (also found in Dassault’s FalconEye) and has six sensors, from visible to longwave infrared. The visible sensor is for detecting LED lights.

SkyLens weighs 650 grams, and the 250-gram display unit that sits in front of the pilot's eyes is offset by a counterbalance on the head harness. If pilots want to remove the SkyLens after takeoff, they can put it in a special storage box then strap it back on before landing.

What sets the NTE HUD apart from traditional HUDs is that the pilot can see on the display any part of the outside world viewable by the sensors mounted on the aircraft but also as represented by synthetic vision.

In a traditional HUD, the pilot can see imagery only in front of the airplane and limited to the 30- to 40-degree field of view of the HUD itself. A pilot wearing the SkyLens can look 180 degrees to the left or right and see synthetic vision imagery of, say, a mountain ridge while flying along a valley, something not possible with a traditional HUD, at least without turning the airplane and pointing it at the ridge.

The SkyLens-wearing pilot also is not constrained to sitting at a specific position that optimizes the view through the HUD, because the NTE HUD is strapped to and moves along with the head.

In addition to airline retrofit opportunities, Yahav believes there is a decent market in business aviation cockpits. "In general if you have a midsize airplane and below, it's hard to get a reasonable [retrofit] offering," he said. "This is an option."

In addition to the undisclosed ATR 72 customer, Elbit is also working with a customer

Elbit SkyLens



that wants to certify SkyLens in various Leonardo helicopters. "We've been flying this for a long time," Yahav said. Elbit is also working with the FAA to equip the agency's research Sikorsky S-76 with SkyLens.

The EASA is supporting the FAA's approach to the new EFVS rules, Yahav said. "In India and China there is big interest in EFVS technology for flying in smog, and they have indicated they will adopt the [FAA] rules as they are today."

Thales is targeting the wearable NTE HUD market with the TopMax head-worn display. A prototype display has been flight-testing aboard turboprop aircraft and in a simulator. TopMax can merge infrared images and synthetic vision, and display traffic information from ADS-B or TCAS. Compared with a conventional aircraft-mounted head-up display, TopMax provides an unlimited field of vision and easier installation at half the cost, according to Thales. □

NEW EFVS RULES BENEFIT HUD OPS

The new rules on the use of enhanced flight vision systems (EFVS) instead of natural vision to descend below 100 feet above touchdown and also land and roll out, issued on December 16 last year, make EFVS equipment even more valuable.

Under the regulation, pilots can continue past 100 feet to touchdown and rollout, flying the airplane, but looking through a HUD and seeing the approach lights and runway lights and markings as EFVS imagery.

Notably, the new rule does not specify the type of sensor required in an EFVS, leaving it to industry to develop and certify new technology that may replace infrared sensors or use them in new ways, or married to other sensors that help the pilot see the runway and its environment. While the old rule required a HUD, the new rule allows other types of image-delivery mechanism, leaving the door open for new products such as wearable HUDs. Head-down displays (instrument panel displays) cannot be used for EFVS operations, however, but the copilot in a two-pilot aircraft can use a head-down display to monitor the pilot's view through the HUD.

According to the AC, "We have made every attempt to write EFVS regulations that are performance-based and not limited to a specific sensor technology. The regulations accommodate future growth in real-time sensor technologies used in most EFVSs and maximize the benefits of rapidly evolving instrument approach procedures (IAP) and advanced flight-deck technology to improve safety and access during low-visibility operations."

Approaches that meet the criteria for EFVS operations to touchdown and rollout are standard IAP or special IAP with a decision altitude (DA) for precision approaches, or decision height (DH) for approach procedures with vertical guidance (APV). In some cases, pilots may also fly certain non-precision approaches (those that use a minimum descent altitude as a DA/DH) using EFVS, with OpSpec C073, MSPEC MC073 or LOA C073 approval.

EFVS operations are not permitted for circling approaches, so pilots can't use EFVS to view "an identifiable part of the airport" to descend below minimum descent altitude (MDA); they must use natural vision. However, the AC does go on to note that pilots can use the EFVS "to supplement natural vision and improve situational awareness at any time."

It should be noted that the enhanced visibility facilitated by the EFVS cannot be less than the visibility specified for the particular approach procedure.

Operators might need specific approvals for EFVS operations. Part 91 operators are not required to obtain approval for operations to 100 feet above TDZE, but they will need approval—OpSpec, MSPEC or letter of authorization (LOA)—for EFVS operations to touchdown and rollout. Commercial operators (91K, 121, 125, 129 or 135) need OpSpec, MSPEC or LOA approval for both types (to 100 feet and rollout/touchdown).

An added benefit for commercial operators is that they can receive approval for dispatching or releasing a flight with low takeoff minimums and "beginning or continuing an approach when the visibility is reported to be less than the visibility minimums prescribed for the IAP to be flown.

—M.T.