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The FAA and University of Iowa Operator Performance Laboratory collect data on Degraded Visual Environment solutions with an eye to civil helicopter certification.

By Frank Colucci

Military rotorcraft solutions for Degraded Visual Environments (DVE) integrate new sensors, pilot cues and flight control laws. The US Army is testing DVE-Mitigation (DVE-M) technologies on a Black Hawk, and the Air Force is in a critical design review on a Degraded Visual Environment System (DVES) for its Pave Hawk. For civil helicopters, the FAA William J. Hughes Technical Center near Atlantic City, New Jersey, continues to partner with academia and industry to test existing sensor and display technology.

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The FAA Tech Center teamed with the University of Iowa Operator Performance Laboratory (OPL) last June to fly DVE approaches in a Mi Mi-2 research helicopter and compare sensors and symbology on helmet-mounted and head-down displays (HMDs and HDDs). The draft report combines data from the Mi-2 flights with previous trials flown on the FAA's S-76 Helicopter from 2016 to 2018. Collaborative investigations into sensor field-of-view, effective visual cues and other performance areas aim to help the FAA
offer guidance and shape policy and rules to use enhanced vision technology under specific conditions. Johnson acknowledged, “there are several operators who want to use the technology but don’t have a regulatory basis or adequate guidance to use the technology to its fullest extent today.”

The FAA already allows fixed-wing operators safety or operational credits for enhanced flight vision systems (EFVS) under Title 14 of the Code of Federal Regulations Part 91.176. According to Johnson, “These systems provide what is known as ‘visual advantage,’ which helps to qualify how much of a landing credit on an approach can be provided for a particular operation when using enhanced vision as part of an enhanced flight vision system....”

Fixed-wing EFVS systems use head-up displays (HUDs) to show pilots aircraft information, flight symbology and the real-time sensor image of the outside world. Though stationary HUDs and forward-looking sensors may work in airplanes penetrating fog or other obscurants, helicopters have less cockpit space for fixed displays. Helmet displays and scanning sensors can show helicopter pilots enhanced vision system imagery, synthetic vision imagery and helicopter flight symbology synced to head movements via a head-tracker.

Most EFVS for fixed-wing aircraft use cooled or uncooled infrared imagers, in some cases fused with visible light or other sensors. According to Johnson, cooled IR sensors generally do a good job of imaging airport environments required under Part 91.176. However, they can be limited in their ability to see through maritime fog and image non-infrared LED lights. Rescue, medevac and law enforcement helicopters often fly into unprepared landing zones without markings, exacerbating the differences.

Johnson noted, “On top of that, due to helipads often being located in obstacle-rich environments in urban or rural areas, typically steeper approaches are flown, often with the landing site miles away from the final approach fix and not necessarily aligned with the final approach course.” He added, “During approach and landing, it is not uncommon for a helicopter to raise its nose in order to slow down and come to a hover, or to turn its nose away in order to see the helipad environment. However, unlike a [fixed-wing] flare when you are already at the runway environment or you see a flare-cue like you do with an EFVS, the helicopter flare-equivalent happens prior to reaching the helipad. Fixed-wing aircraft land and slow down whereas helicopters slow down and land. The idea is that, taken together, these qualities in how helicopters fly could necessitate a wider field-of-view in both the lateral and vertical directions.”

While airliners or business jets are relatively easy to fly to the end of a runway marked on a HUD, low-speed helicopters going through translational lift close to the ground increase pilot workload. “Now you’re flying a machine that’s traditionally not stable,” said Schnell. “I have a lot more dependency on good cueing for pitch, roll and yaw and the translational axes that you wouldn’t have in a fixed-wing airplane.” He added, “Given that in standard helicopters stability augmentation is not much or not at all, that’s harder to control.”

The OPL conducts human-in-the-loop research on synthetic vision and enhanced vision systems head-up and head-worn displays optimized symbology. Human factors data from the flight trials will shape systems requirements for certification. OPL is determining the effectiveness of lidar in detecting obstacles for en route and landing zone evaluation under a range of environmental conditions.

**Trying Eyes**

An OPL pilot flew the Lab’s Mi-2 helicopter in desert brownout conditions at Yuma Proving Ground, Arizona, in 2016 during DVE-M trials for the US Army and NATO. The helicopter carried a...
Hensoldt SferiSense 500 lidar on a left-side outrigger. According to the manufacturer, the active-scanning laser radar detects terrain and unspecified obstacles out to 0.75 miles (1,200 m). The lidar was modified with dust-filtering software for the Yuma trials. It generated color flight symbology on a BAE Systems Striker II HMD and a HDD of the Collins Aerospace common avionics architecture system (CAAS) in the test helicopter.

The Striker II head tracking system (see “Heads Up, Eyes Out, All Around,” Vertiflite, Sept/Oct 2018) allowed symbology to be projected on the helmet visor conforming to real-world terrain and obstacles. The HDD superimposed symbology from the lidar over short-wave infrared imagery generated by a Goodrich short-wave infrared (SWIR) video camera and an ASI visible light camera on the sensor outrigger. Head-up and head-down displays could show the pilot different subsets of sensors and data concurrently. Significantly, the Yuma test pilot preferred a minimized, decluttered symbol set on the HMD and more complete symbology on the HDD.

The Striker II helmet was returned to the supplier after the desert tests, but the same lidar was tied to a monochrome green helmet display from SA Photonics and a new Hensoldt Optronics head tracking system last year for the FAA investigation. A Canon ME20F-SH low-light video camera was installed in the left chin window and interfaced with the cockpit displays and computers to provide background imagery in the HDD day and night and in the helmet display at night. The color camera was modified to become a monochrome sensor with nearly 5.5 million ISO sensitivity and a response in the near-infrared region. Schnell offered, “That camera, the ME20F, is an absolutely amazing camera. In my opinion, every helicopter should have one. It gets you images at night at least as clear as daytime.”

A Sony UMC-S3C camera in the right chin bubble provided visible light performance like the human eye. The CMOS camera was fitted with a green filter with a spectral transmission function like the human photopic (color sensing cone cell) vision. OPL software turned red-green-blue color levels into calibrated luminance values. “Therefore, we now have a 60 frames/sec, very sensitive and accurate real-time digital photometer. This helps when we want to know how far you can see object x-y-z; we need to know how bright it is.”

Researchers cropped the camera image to make Hensoldt symbology conform to real-world details. The lidar had both a built-in geographic database and the algorithms to determine that vertically aligned returns meant there was a tower. T-symbols used to represent towers, for example, could come from real-time sensor returns or the stored database. “If you have a database of objects, they’d show up and you would not know the difference,” explained Schnell. “We don’t want to you to be concerned where they come from — it’s a tower.”

OPL built an experimental helipad at the Iowa City Municipal Airport using FAA engineering standards. Airport beacons, windsocks and other targets of interest selected by the FAA View through the OPL helmet mounted display with all sensors and symbology engaged shows “voxels” and conformal symbology in a cluttered view.
were identified at the airport. Test pilots flew day and night approaches to the helipad and an airport runway landing zone in unlimited visibility and in fog and light rain. They used different combinations of symbology, synthetic vision and enhanced vision on both the head-up and head-down displays.

Target detection ranges and other data was collected using the OPL cognitive assessment tool set (CATS) that also recorded weather conditions from the airport automated surface observing system and flight state from the helicopter inertial navigation system. A cockpit camera recorded imagery and symbology on the head-down multi-function displays, and a helmet camera captured the HMD view with its real-time symbology.

Preliminary findings noted the Mi-2 test pilot liked the vision systems and appreciated the sensor enhancements more as visibility degraded. Researchers payed special attention to de-cluttering helmet displays in the already-cluttered helicopter environment. “You cannot just take a head-down symbology set and shove it into a helmet,” said Schnell. “You can’t see through it. You can’t see the real world behind it.” Pilots did use both head-up and head-down displays to distinguish obstacles from clumps of “voxels,” or volume pixel returns. “As a pilot flying with an HMD, I would not put them in my face,” acknowledged Schnell. “But when I pick up a tower, I take a quick glance at my head-down display so I get trust in the lidar’s ability to detect an obstacle.”

With different sensors in play, experimenters confirmed visible-light cameras degrade just like the human eye in fog and rain. Infrared imagery penetrates obscurants to some extent and lidar likewise provides some penetration. “There’s no magic bullet,” concluded Schnell. “About the only thing you can count on to penetrate would be millimeter wave radar, which we didn’t have.”

OPL researchers plan further tests with an SA Photonics color helmet display in place of the monochrome display. “It looks great,” observed Schnell. “We haven’t collected data.” Color has long been used as a way to enhance cockpit warnings, and conformal color cues may help call out hazards. “I think even if you had three colors, it would be good, maybe four. Having a lot more is probably not necessary.” Within the last few feet before touchdown, a helmet display might even turn itself off to clear the landing zone. “I think there’s a lot more work to be done where the helmet display might be aware of what your eyes see and feather-out to show less and less camera image.”

**Returns to Rules**

Civil DVE mitigation technologies can get certified via supplemental type certificates on existing helicopters, type certificates on new aircraft or with non-required safety enhancing equipment (NORSEE) approval. Cliff Johnson explained, “A system that is in the pilot’s primary field of view on a head-up display being used for operational credit would likely have different and higher certification and operational requirements to meet than a system used purely for enhancing safety.”

For the FAA, the end-game of the research is performance-based standards, policy and guidance. According to Johnson, findings will be published and circulated within the FAA Tech Center program office and among other stakeholders in the agency including NextGen airspace, flight standards, aircraft certification and the FAA’s Rotorcraft Standards Branch experts. Data will also go to the US Helicopter Safety Team (USHST) as it addresses a “Helicopter Safety Enhancement” (HSE-91) on vision systems technology. The FAA Tech Center program office also participates in industry working groups that will develop standards for enhanced vision technologies.

The FAA is also collaborating with LifeFlight of Maine on a demonstration project to research an enhanced vision system as one part of an integrated low-level instrument flight rules (IFR) approach, departure and route system covering the rugged state and its islands. According to LifeFlight of Maine executive director Thomas Judge, “EVS is an important technology in a systems approach to low-level IFR.” The fully integrated system would enable helicopter pilots to reach more patients in areas where ceiling and visibility fall below required minima. “Incorporating EVS certified for approach credit will allow us to safely reduce the required minima in lowered visibility conditions to our procedures while maintaining the highest level of safety and situational awareness for our pilots.”

Helicopter enhanced vision systems for degraded visual environments have a growing technical foundation, and the FAA Tech Center’s Johnson concluded, “If we follow the path that was taken for fixed-wing, utilizing lessons learned but respecting and acknowledging the differences and challenges in rotorcraft, I believe we will develop a DVE solution for the civilian vertical lift community. That will help in reducing the helicopter fatal accident rate and expanding efficiency for low-visibility approaches.”

**About the Author**

Senior contributing editor Frank Colucci has written for Vertiflite for the past 20+ years on a range of subjects, including rotorcraft design, civil and military operations, testing, advanced materials, and systems integration. He can be reached at rotorfrank@aol.com.