Cue Me

By Frank Colucci

Integrating visual, aural and tactile cues promises to reduce workload and enhance safety in Degraded Visual Environments

A CH-47 Chinook helicopter creates white-out conditions as it lands in Afghanistan in Feb. 2012. An Integrated Cueing Environment promises crews visual, tactile and aural cues in such high-workload situations. (DOD)

An Integrated Cueing Environment (ICE) blending visual, aural and tactile pilotage cues is one piece of the Degraded Visual Environment Mitigation (DVE-M) roadmap drawn by the US Army Aviation Research, Development and Engineering Center (AMRDEC). Within upcoming DVE-M Science and Technology demonstrations, the Army Research Laboratory (ARL) has the lead for ICE. Dr. Thomas Davis, Chief of the ARL Air and C2 Systems Branch, offered, "What the Integrated Cueing Environment does is assist pilots in making better decisions and choices, not just in landings and takeoffs, but enroute as well." He added, "One of the reasons we're doing this is, after over a decade of war, the top leadership have recognized we have a survivability problem with DVE and we also lack the capability to deliberately enter DVE and use it to our tactical advantage. The Army's way to investigate the material contributors to solving these challenges is DVE-M. That is the thrust of why we're doing what we're doing. To make sure our pilots can go out, fight the fight, and make it back home, regardless of the environment."

Army helicopters today lack the capability to operate in a deliberate, tactical manner in all forms of DVE. DVE-M consequently goes beyond the dangers of brownout landings in desert dust and aims to turn darkness, fog and other degraded visibility conditions into a battlefield advantage (see "Bigger Than Brownout," *Vertiflite*, July/August 2015). Complementary technologies will fly on an Aeroflightdynamics Directorate (AFDD) UH-60L research helicopter at Yuma Proving Ground, Arizona, this September and in Germany and Switzerland in February 2017. The Black Hawk demonstrator will integrate Modernized Control Laws (MCLAWS); radar, LADAR (LAser Detection and Ranging) and long-wave infrared sensors; and a baseline visual, aural and tactile cueing suite.

Production DVE-M materiel solutions may get to fleet cockpits through the DVE/BORES (Brownout Rotorcraft Enhancement System) or DVEPS (DVE Pilotage System) programs led by the Army Program Executive Office (PEO) Aviation and the US Special Operations Command, or via the Army Attack, Utility, and Cargo Helicopter Program Managers. The Product Manager Air Warrior is developing a Modular Integrated Helmet Display System (MIHDS) with a wide field-of-view (FOV) color display for DVE symbology, three-dimensional audio and integrated head tracker. "Bottom line," said Davis, "the ultimate goal of DVE-M is to provide the knowledge base for the acquisition of an affordable and practical DVE system in the future consisting of a combination of cueing, sensors and advanced flight controls."

The Army Communications-Electronics Research Development and Engineering Center (CERDEC) is pursuing sensor technologies for DVE-M, and AMRDEC itself has responsibility for both flight controls and the complex computing that integrates the solution. The cueing portion of DVE-M as envisioned by ARL augments advanced two- or three-dimensional visual symbology and fused sensor imagery (ICE-V) with aural (ICE-A) and haptic/tactile (ICE-T) cues.

An acknowledged challenge of ICE system design is to ensure that cues don't overload busy pilots. Davis explained, "Overreliance on any one sensory channel, especially during periods of high workload, can also cause cognitive tunneling and sensory bottleneck. Thus, the ICE system utilizes visual, aural and tactile cueing. Aural cues have the ability to capture a pilot's attention and elicit an urgent response regardless of head position

The US Army Aeromedical Research Laboratory has a UH-60 simulator able to collect crew biometrics in simulated Degraded Visual Environments. (USAARL)

or eye fixation, while tactile cues result in minimal interference with visual and aural information processing channels."

ICE-T researcher Dr. Angus Rupert at the US Army Aeromedical Research Laboratory (USAARL) summarized, "When the three systems are correctly integrated, pilot workload significantly decreases, especially in the DVE. When all three sensory modalities are providing redundant orientation information, spatial disorientation is less likely to occur." USAARL conducted its first Pilot Cueing Synergy Experiment in June 2014 and subsequently proposed synergizing pilot cues to improve situational awareness for DVE-M. Just how much better pilot performance can be with ICE will be further quantified by a new simulator study this April. The Fort Rucker Lab, Alabama, has its own full-motion, Level-D visual quality UH-60A/L simulator in an environmental chamber capable of cockpit temperatures to 105°F and noise levels to 120 dB. "Ours is very unique," noted Flight Systems Branch Chief and Lead Research Pilot John Ramiccio. Researchers can measure pilot heart rate, heart rate variability and other biometrics in realistic flight conditions. Many of the biometrics are being applied to the DVE-M experiments. "We've got empirical proof of workload and situational awareness."

AMRDEC takes a demonstrate-fix-demonstrate approach to DVE-M, and Ramiccio added, "Before USAARL got involved in these experiments, they really had only the qualitative data [pilot perceptions]. Now, we give them the performance data." Simulator data will further refine cueing modalities and their integration for DVE-M. "When you go to flight test, you've got the best of the breed [solution], so it saves money in the flight test environment."

ICE Visual

A bolt-on façade changes the USAARL simulator cockpit from legacy UH-60A/L instruments to modern UH-60M displays, and researchers will try ICE-V symbology on both Panel Mounted Displays (PMDs) and head-tracked, binocular, wide-field-of-view Helmet Mounted Displays (HMDs). Dr. Davis at ARL said, "We're investigating the trade space to see is there anything we're missing in the Helmet Mounted Display to make it just as good or better than the Panel Mounted Display." The commercial HMD being used in the April 2016 DVE-M experiments affords a 60° field of view. "How wide of a field of view is optimal? That's one of the things we hope to add to the body of knowledge." The HMD will work with a Thales Visionex head-tracker like that installed on the AFDD Black Hawk at Moffett Field, California.

USAARL ICE-V researcher Tom Harding offered, "Synthetic vision and 3-D symbology are technologies that are being developed to assist the aviator in maintaining a visual awareness of their aircraft with respect to key terrain features, objects, landing sites,

The USAARL simulator can display ICE-V symbology on Panel Mounted Displays. ICE-V symbology evolved from BOSS – the Brown-Out Symbology System -- and provides 2-D cues enroute and 3-D conformal symbology near the Landing Zone. (USAARL) navigation, and the like." He adds,

"Our approach is to expand the Panel Mounted Display-based visual cueing symbology and guidance technology from a limited maneuver set (hover and landing) to all DVE operating environments (taxi, takeoff, enroute, hover, and landing) on both PMD and HMD while integrating aural and haptic technologies where appropriate."

The BrownOut Symbology System (BOSS) developed by AFDD and NASA Ames researchers (see "Enlightened Landings," *Vertiflite*, Spring 2010) has been superseded by ICE-V with 2-D hover and flight symbology and 3-D conformal symbology. The DVE-M Cueing Integrated Product Team "took the best attributes of BOSS and used them in ICE-V symbology," said Ramiccio. "It has evolved, become more high performing, more intuitive."

ICE-V three-dimensional conformal symbology provides a perspective view of a landing point and flight path markers with terrain warnings and a "pathway in the sky" for route navigation. A fused sensor picture of the terrain on the PMD and/or head-tracked HMD enables the pilot to see through blinding weather. "What you are seeing is conformal to the real world," noted Dr. Davis. "You're getting a real-world view." ICE-V also provides horizontal and vertical guidance cues, which will help the pilot to establish a precise hover or land exactly at the intended point.

Aural and Tactile

The objective of the Integrated Cueing Environment is to allow for pilotage in all operating environments with seamless transition from day through night, rain, snow, fog or dust. Depending on flight mode and task, ICE supplements what pilots see with what they hear and feel. Aural and tactile cues may enhance awareness of aircraft state with respect to drift, navigation and altitude hold. They may also improve threat awareness. John Ramiccio at USAARL said, "That really is the crux of what we do here, harmonizing which cue is best for which mode of flight."

Military and commercial aircraft routinely use 2-D tones, alarms and artificial voices to cue pilots. However, Dr. Davis at ARL observed, "Monaural audio does not offer the spatial separation you get in 3-D audio. With

Trials in the USAARL simulator will evaluate ICE-V symbology on both Panel Mounted Displays (PMDs) and head-tracked, binocular, wide-field-of-view Helmet Mounted Displays (HMDs). (USAARL)

3-D audio, we envision in those high-workload tasks where there is a lot of communication between ground control, crew and pilot, we can spatially separate those conversations. ARL and NASA as well have done quite a bit of research in that area. We know 3-D audio is beneficial. We're trying to determine how beneficial is it in headsets and high-audio workload situations like hovering and landing."

Hover-hold performance is also improved with haptic/touch cues, according to John Ramiccio at USAARL. The Fort Rucker lab used its JUH-60A research helicopter and six pilots to validate the Tactile Situational Awareness System (TSAS) in 2013 (see "Fly It With Feeling," *Vertiflite*, November/December 2013). "My favorite is terrain avoidance, enroute flying using the seat pan to buzz when you've descended below the altitude you intended. The seat pan cue has become a strong favorite with the research pilots. The midbrain tells your left hand to pull up."

Dr. Rupert offered, "Currently, USAARL is focused on TSAS, but there are other tactile cues that have been used such as rudder shakers to warn of an impending stall. Collective and cyclic shakers are being explored as well (not at USAARL). The DVE-M Cueing Integrated Product Team is exploring several haptic types of technologies. These include components of USAARL's tactile system composed of belt, seat pan and shoulder tactors [sensation generators], tactile gloves, and haptic controls such as collective and/or cyclic stick shakers." The upcoming simulator cueing trial and DVE-M flight test are not testing haptic gloves or stick shakers, but ICE will give the Science and Technology demonstration a chance to evaluate TSAS, aural, and visual cueing in one integrated scheme. "Industry has been developing individual components, but does not yet have the latest of all three technologies flying together."

Pieces of the Picture

The current CH-47F, UH-60M and AH-64E models all have digital Automatic Flight Control Systems that improve brownout landing safety. While AMRDEC integrates cueing, sensors and flight control laws for Degraded Visual Environment Mitigation, industry and other government entities are pursuing their own pieces of the DVE puzzle. The US Army Medical Department (AMEDD), for example, is sponsoring the Situational Awareness and Vision Enhancement System (SAVES) to give a limited number of HH-60M MEDEVAC helicopters improved capability to find patients and isolated personnel in light rain, light fog and certain types of dust. An uncooled long-wave infrared sensor will be added to the FLIR Systems AN/AAQ-22 Star SAFIRE II gimbal on MEDEVAC Black Hawks, but no changes to HH-60M displays or symbology are planned. The interim, low-cost DVE capability will not be designed or approved for pilotage.

Honeywell Aerospace adapted its commercial Synthetic Vision Aviation Backbone (SVAB) to the DARPA Multi-Role, Multi-Function (MFRF) technology demonstration. (Honeywell)

The Defense Advanced Research Projects Agency (DARPA) Multi-Function Radio Frequency (MFRF) initiative ties a high-resolution W-band RF sensor to a Synthetic Vision Avionics Backbone (SVAB) but does not develop new displays or symbology. The SVAB from Honeywell Aerospace fuses stored databases with real-time sensor data for an out-the-window view. Honeywell Senior Manager Howard Wiebold explained. "You can use whatever symbology you want. The symbology really isn't an issue for us. Our focus is an accurate picture." MFRF testing plans conclude with a tower test this year. DARPA and the Army are considering flight tests in Fiscal 2017.

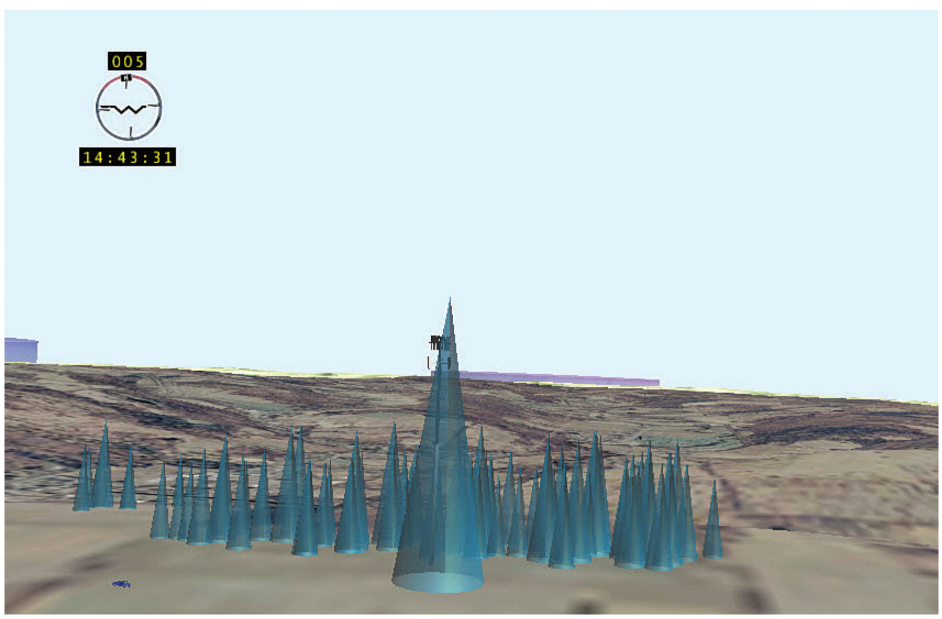
Boeing Mesa is talking to the Army Training and Doctrine Command (TRADOC) about improving the AH-64E Pilot-Vehicle Interface. Paul Meyers, Boeing Program Manager for Attack Helicopter Modernization observes, "For us, as an attack aircraft, what DVE means is different from a cargo or utility aircraft. The brownout landing isn't really an Apache issue — they don't land out in forward areas as much as a cargo or utility helicopter. The attack community wants to operate in the full spectrum of missions regardless of weather." Meyers adds, "Since the Apache already has a lot of sensors on it, we're working with Lockheed Martin and Northrop Grumman — the sensor makers — and trying to see where they see the technology going. We're trying to see, based on user requirements and projected performance, what kind of capability we can provide, and are there gaps."

Larger cockpit displays are a starting point. "The intent is to improve the situational awareness of the crew, so the crew can more quickly absorb all the data being sent to them," said Meyers. The Apache monocular Integrated Helmet Display and Sighting System (IHADSS) with its 40° FOV is likewise target for improvement. "If we redesign the cockpit and redo our displays, what's the tradeoff of large-area displays and a helmet display?" Haptic cueing can signal hover drift, performance limits or sensed obstacles. "We can manage and have programmable detents — stops and hard-stop feels. We can change what those stops mean based on the condition of the aircraft. . . . It's an upgrade to the existing flight control system. We don't necessarily have to go to a fly-by-wire system."

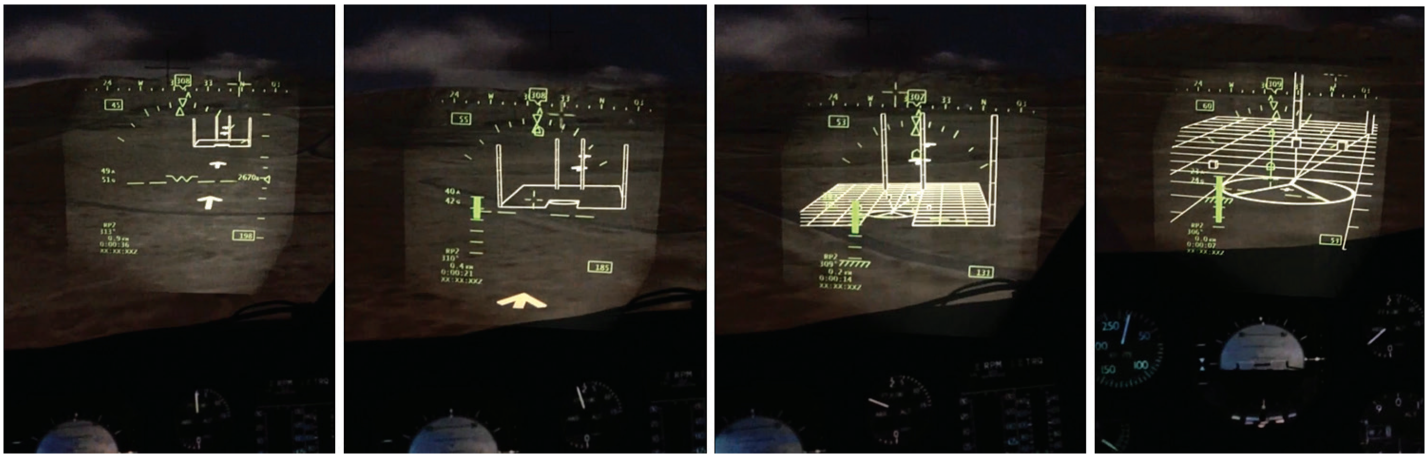
Lockheed Martin Mission Systems and Training meanwhile continues sensor tests on its UH-1 Flying Test Bed with the DVECTOR (Degraded Visual Environment Correlation Tracking & Obstacle Recognition) system (see "One Picture, Different Eyes," *Vertiflite*, September/October 2012). The sensors are georeferenced in a 3-D obstacle database coupled with a Tactical Synthetic Vision System. The Huey, for example, flew with the APQ-187 Silent Knight radar at Redstone Arsenal using symbology and cueing from the Special Operations Aircraft Integrated Avionics System (IAS). Terrain Following/Terrain Avoidance cues on the flight director provided a directive collective position indicator while symbology showed aircraft state, power available and ability to climb over detected terrain or cue a turn away. The DVECTOR Huey also tried a rudimentary tactile cueing system.

ENSCO Avionics markets the flexible SVS Core 2.0 application baseline used to generate imagery for the DVECTOR pilot. ENSCO General Manager for Human-Machine Interface products Larissa Parks explained, "We have in-house CONOPS [Concept of Operations] experts who determine the optimal view and experience for the operator — how would you like objects to appear, when would you. All of that is tailorable."

Elbit Systems of American and ARL are testing conformal cockpit symbology for Landing Zone/Pickup



ENSCO Avionics developed the flexible SVS Core 2.0 application baseline to generate synthetic vision imagery. (ENSCO)



Elbit Systems of America has developed a 3D Conformal Symbology scheme that cues the pilot with more data on approach. (Elbit Systems of America)

Zone operations and a Helmet Display Tracking System that gives pilots wearing Night Vision Goggles (NVGs) "augmented reality." Dennis McIntire, Master Army Aviator and now Elbit Business Director for Airborne Solutions said, "The key point for the symbology is that it's intuitive. . . . We're trying to take away the need to interpret what the instruments are saying and fly like you're in a video game." The Operational Test system on a Black Hawk at the Army's Aviation Applied Technology Directorate (AATD) introduces a Helmet Display and Tracker System. A substitute right-eye AVS-9 eyepiece overlays 3-D color symbology on NVG imagery. The system uses a helmet tracker like that in the AH-64E Apache.

Elbit's augmented reality correlated two types of symbology with Digital Terrain Elevation Data, GPS and radar altimeter inputs. Enroute, a wire frame over mountains and other terrain highlights real ground features registered with flight symbology through NVGs. Approaching the programmed Landing Zone or Pickup Zone (LZ/PZ), symbology defines the target with a box that fills with additional information as distance closes. Near the LZ/PZ, segmented towers provide vertical and drift cues for landing. The LZ picture shows slope of the ground derived from Digital Terrain Elevation Data (DTED). As a near-term DVE aid, the test system is not coupled to aircraft flight controls or a see-through sensor. Dennis McIntire concluded, "We know we have flight control laws that work. We know symbology with cueing works. When the sensor comes along, it can be integrated as well. One thing doesn't threaten the other."

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 emailed at **rotorfrank@aol.com**.

An AMRDEC UH-60 test aircraft generates a brownout dust cloud. The AMRDEC DVE-M program aims to mitigate brownout and other Degraded Visual Environments with integrated pilot cueing, advanced flight controls, and see-through sensors. (US Army Research Laboratory)