



# Advisory Circular

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**Subject:** Enhanced Flight Vision Systems

**Date:** 6/2/10

**AC No:** 90-106

**Initiated by:** AFS-400

**1. PURPOSE.** This advisory circular (AC) provides information to an applicant pursuing airworthiness certification and operational approval of an enhanced flight vision system (EFVS). It is an acceptable, but not the only, means of obtaining airworthiness certification and operational approval.

**2. APPLICABILITY.** This AC applies to persons operating aircraft under Title 14 of the Code of Federal Regulations (14 CFR) parts 91, 121, 125, 129 and 135. Under § 91.175(l), a pilot may use an approved EFVS to descend below Decision Altitude (DA) or minimum descent altitude (MDA) to 100 feet above the touchdown zone (TDZ) elevation (TDZE) from a straight-in instrument approach procedure (IAP) other than Category II (CAT II) or Category III (CAT III). These operations are permitted for approaches using straight-in IAPs, but not for circle-to-land operations.

**NOTE: Part 91, § 91.175(l) refers to decision height (DH); however, this AC uses DA. For the purposes of this AC, the terms DA and DH are interchangeable.**

**3. RELATED REFERENCES.**

**a. Title 14 CFR References.** This AC applies to:

- (1) Part 21.
  - (2) Part 23.
  - (3) Part 25.
  - (4) Part 27.
  - (5) Part 29.
  - (6) Part 91, § 91.175(l) and (m).
  - (7) Part 121, § 121.651.
  - (8) Part 125, § 125.381.
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(9) Part 135, § 135.225.

**b. Related Material (current editions).**

(1) AC 20-115, RTCA, Inc., RTCA/DO-178B.

(2) AC 20-136, Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning.

(3) AC 20-145, Guidance for Integrated Modular Avionics (IMA) that Implement TSO-C153 Authorized Hardware Elements.

(4) AC 20-152, RTCA, Inc., Document RTCA/DO-254, Design Assurance Guidance For Airborne Electronic Hardware.

(5) AC 21-16, RTCA, Document DO-160 Versions D, E, and F, Environmental Conditions and Test Procedures for Airborne Equipment.

(6) AC 23.1309-1, System Safety Analysis and Assessment for Part 23 Airplanes.

(7) AC 23.1311-1, Installation of Electronic Displays in Part 23 Airplanes.

(8) AC 25-11, Electronic Flight Deck Displays.

(9) AC 25.773-1, Pilot Compartment View Design Considerations.

(10) AC 25.1309-1, System Design and Analysis.

(11) AC 120-28, Criteria for Approval of CAT III Weather Minima for Takeoff, Landing, and Rollout.

(12) AC 120-29, Criteria for Approval of Category I and Category II Weather Minima for Approach.

(13) AC 120-71, Standard Operating Procedures for Flight Deck Crewmembers.

(14) Federal Aviation Administration (FAA) Order 8110.49, Software Approval Guidelines.

(15) FAA Policy Memorandum PS-ANM100-1992-00057, Airspeed Displays for Electronic Flight Instruments Systems (EFIS), dated February 26, 1992.

(16) FAA Policy Memorandum PS-ANM100-1996-00056, Low and High Speed Awareness Cues for Linear Tape Airspeed Displays, dated September 11, 1996.

**NOTE: ACs and Policy Memorandums may be obtained by clicking on the link “Regulatory and Guidance Library” on the FAA public Web site: <http://www.faa.gov/>.**

(17) Society of Automotive Engineers (SAE) Aerospace Standard 8055, Minimum Performance Standard for Airborne Head Up Display, dated March 1, 1999.

(18) SAE Aerospace Recommended Practice (ARP) 5288, Transport Category Airplane Head-up Display Systems, dated May 1, 2001.

(19) SAE ARP 4256A, Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft, dated December 14, 2001.

(20) RTCA DO-315, Minimum Aviation System Performance Standards for Enhanced Vision Systems (EVS), Synthetic Vision Systems (SVS), Combined Vision Systems (CVS), and Enhanced Flight Vision Systems (EFVS), dated December 16, 2008.

(21) RTCA DO-178B, Software Considerations in Airborne Systems and Equipment Certifications, dated December 1, 1992, with errata issued March 26, 1999.

(22) SAE Aerospace Standard, AS 8034A, Minimum Performance Standard for Airborne Multipurpose Electronic Displays, dated July 13, 2005.

(23) Flight Standardization Board (FSB) reports. <http://www.opspecs.com>.

(24) FAA National Simulator Program (NSP) information. [http://www.faa.gov/safety/programs\\_initiatives/aircraft\\_aviation/nsp/](http://www.faa.gov/safety/programs_initiatives/aircraft_aviation/nsp/).

(25) Special Conditions: Enhanced Vision System (EVS) for Gulfstream Model G-V Airplanes, 66 FR 32717, dated June 18, 2001.

**4. DEFINITIONS.** Acronyms and abbreviations are contained in Appendix 1 of this AC. Definitions are contained in Appendix 2.

## **5. BACKGROUND.**

**a. History.** For many years, § 91.175 prescribed flight visibility requirements using the pilot's natural vision to identify the approach lights and the runway environment when operating an aircraft under instrument flight rules (IFR). Until Amendment 91-281 (69 FR 1620, January 9, 2004) [Docket Number FAA-2003-14449], § 91.175 did not allow descent and landing if the pilot could not see certain required visual references with his or her natural vision.

**b. EFVS Overview.** Amendment 91-281 revised § 91.175 to allow a pilot to descend below DA or MDA from a straight-in IAP other than CAT II or CAT III using an EFVS. An EFVS uses imaging-sensor technologies, which may be based on forward looking infrared, millimeter wave radiometry, millimeter wave radar, low level light intensification, or other technologies, to provide a real-time enhanced image of the external scene topography to the pilot. Amendment 91-281 also introduced the term "enhanced flight visibility," which is defined in 14 CFR part 1, § 1.1 as the "average forward horizontal distance, from the cockpit of an aircraft in flight, at which prominent topographical objects may be clearly distinguished and identified by day or night by a pilot using an enhanced flight vision system." Additionally, this amendment specified new requirements for descending below DA or MDA using an EFVS.

(1) To descend below DA or MDA using an EFVS, the enhanced flight visibility observed by the EFVS cannot be less than the visibility prescribed in the IAP being flown, and the visual references required by the regulations must be distinctly visible and identifiable to the pilot using the EFVS. This revision of the regulations permits a pilot to use an EFVS to do the following when the runway environment may not be visible to a pilot relying on natural vision alone:

- Determine that the enhanced flight visibility is not less than the visibility prescribed by the IAP being used,
- Identify the required visual references,
- Verify proper runway alignment, and
- Descend from DA or MDA down to 100 feet above the TDZE of the runway of intended landing.

(2) To descend below 100 feet above the TDZE of the runway of intended landing, the pilot must be able to see the visual references required by § 91.175(l)(4) with his or her natural vision.

## **6. EFVS SYSTEM AND OPERATIONAL REQUIREMENTS.**

**a. Equipment Requirements for EFVS Operations.** An EFVS that is used to conduct operations using a U.S.-registered aircraft under parts 91, 121, 125, 129, and 135 must have an FAA type design approval. For a foreign-registered aircraft used to conduct those operations, the EFVS must comply with all of the EFVS requirements of § 91.175(m). Section 91.175(m) states that an EFVS is an installed airborne system that includes:

- The display element, which is a head-up display (HUD) or an equivalent display, that presents the features and characteristics required by the regulations such that they are clearly visible to the pilot flying in his or her normal position and line of vision looking forward along the flight path,
- Sensors that provide a real-time image of the forward external scene topography, as described above,
- Computers and power supplies,
- Indications, and
- Controls.

**b. Required Flight Information.** In addition to the sensor imagery, at least the following specific aircraft flight information must be displayed:

- Airspeed,

- Vertical speed,
- Aircraft attitude,
- Heading,
- Altitude,
- Command guidance as appropriate for the approach to be flown,
- Path deviation indications (e.g., equivalent to instrument landing system (ILS) glideslope (GS)/localizer (LOC) or as appropriate to the approach),
- Flight Path Vector (FPV), and
- Flight Path Angle (FPA) reference cue.

**c. Additional Requirements.** The regulations also specify that the EFVS imagery, attitude symbology, FPV, FPA reference cue, and other cues which are referenced to the imagery and external scene topography must be conformal (i.e., they must be aligned with and scaled to the external view). In addition, the FPA reference cue must be displayed with the pitch scale, and the pilot must be able to select the appropriate descent angle for the approach. Finally, the display characteristics and dynamics must be suitable for manual control of the aircraft.

**d. EFVS and Enhanced Vision Systems (EVS).** An EFVS should not be confused with an EVS. An EVS is an electronic means to provide the flightcrew with a sensor-derived or enhanced image of the external scene (e.g., millimeter wave radar, forward looking infrared (FLIR)). Unlike an EFVS, an EVS does not necessarily provide the additional flight information or symbology required by § 91.175(m). For example, an EVS may be presented on a head down display and may not be able to present the image and flight symbology in the same scale and alignment as the outside view. Such a system may provide situation awareness to the pilot, but does not meet the regulatory requirements of § 91.175(m). As such, an EVS cannot be used as a means to determine enhanced flight visibility or to identify the required visual references in order to descend below DA or MDA.

**e. Equivalent Display.** The regulations also make provision for an equivalent display. Specifically, § 91.175(m) states that the EFVS sensor imagery and aircraft flight symbology must be presented "...on a head-up display, or an equivalent display, so that they are clearly visible to the pilot flying in his or her normal position and line of vision and looking forward along the flight path..." In other words, an equivalent display must be some type of head-up presentation of the required information. A head-down display (HDD) does not meet the regulatory requirement.

(1) References to HUD and associated criteria are meant to apply to "equivalent displays" as well. However, at this time the actual form and characteristics of such displays are speculative and for them the airworthiness criteria may not be defined. The FAA may require a proof of concept and then establish additional airworthiness criteria for equivalent displays.

(2) An HDD that is used to provide situation awareness for the pilot monitoring (PM) is permitted but not required; however, that display may not be used to maneuver the airplane or to descend below DA or MDA.

## 7. AIRWORTHINESS CERTIFICATION OF EFVS.

**a. Approval.** Amendment 91-281 focused on the requirements for operational approval of EFVS. All EFVS equipment installations must also meet the airworthiness standards in parts 23, 25, 27, or 29 (as applicable).

**b. EFVS and Pilot Compartment View.** In 2001, the FAA issued Special Conditions No. 25-180-SC (66 FR 32717, June 18, 2001) for the airworthiness certification of an EFVS, formerly referred to as an enhanced vision system, on the Gulfstream Model G-V airplane. Special conditions are issued in accordance with part 21, § 21.16 and are based upon a finding that current airworthiness regulations do not contain adequate or appropriate safety standards for a product because of a novel or unusual design feature. Under the authority of § 21.16, the FAA Administrator found that part 25, § 25.773, the regulation applicable to pilot compartment view, did not contain adequate or appropriate safety standards for the airworthiness certification of EFVS as that regulation did not address the display of EFVS imagery. The issuance of the EFVS final rule (Amendment 91-281) did not terminate the need for the issuance of special conditions for EFVS. Therefore, the FAA must issue special conditions that provide for an equivalent level of safety with regard to pilot compartment view for each aircraft model with an EFVS installed. The applicant for airworthiness approval must have their proposed EFVS equipment and installation evaluated under airworthiness criteria similar in scope to that contained in Special Conditions No. 25-180-SC. The FAA will issue appropriate special conditions for each aircraft model that will require the combination of what the pilot sees in, through, and around the EFVS image to be as safe and effective for all pilot tasks requiring the outside view, as if the EFVS image were not displayed at all.

**c. Special Conditions.** Until the FAA revises § 25.773 and corresponding sections in parts 23, 27, and 29 to provide appropriate Airworthiness Standards for EFVS, the FAA will issue special conditions addressing the applicant's EFVS installation on a particular model aircraft.

**d. Appendices.** Appendices 3 and 4 to this AC contain guidance on the airworthiness certification issues that may be raised by the FAA during the airworthiness certification of an applicant's EFVS. These appendices are based on the special conditions issued for the Gulfstream Model G-V airplane and FAA experience in the issuance of that Supplemental Type Certificate (STC). The appendices are general in nature and an applicant's special conditions may necessitate additional or other requirements depending on the complexities of each aircraft model and EFVS installation. The information from this AC should be used by applicants pursuing a type certificate (TC), amended TC, or an STC for an aircraft that includes an EFVS.

## 8. OPERATIONAL USE OF EFVS UNDER § 91.175.

**a. Regulatory Authorization.** Section 91.175(l) provides the regulatory authorization for operators conducting straight-in IAPs other than CAT II or CAT III to operate below the DA and MDA when using an EFVS to obtain a real-time sensor image of the external scene.

**b. Operational Approval for EFVS.** For parts 91 subpart K (91K), 121, 125 (including part 125 Letter of Deviation Authority (LODA) operators), 129, and 135 operators, operational approval to conduct EFVS operations under §§ 91.175(l) and (m), 121.651, 125.381, and 135.225 is given through the issuance of operations specification (OpSpec) C048, management specification (MSpec) MC048, or letter of authorization (LOA) C048. Except for part 91K operators, part 91 operators are not required to be issued an LOA to conduct EFVS operations. Operational approval and the issuance of OpSpec C048, MSpec MC048, or LOA C048 is discussed in more detail in paragraph 11, Operational Approval Process for EFVS. It should be noted that for CAT II and CAT III operations where EFVS may be used for situation awareness (e.g., CAT II or CAT III-certified HUD with EFVS sensor image), the operator must still comply with the aircraft equipment, training, and operational requirements for CAT II or CAT III operations.

**c. Purpose of EFVS.** The EFVS provides a means for the pilot to determine enhanced flight visibility, positively identify visual references for approach operations, and to continue an IAP below the DA or MDA down to 100 feet above the TDZE of the runway of intended landing. At that point and below, the lights or markings of the runway threshold or the lights or markings of the TDZ must be visible to the pilot without using the EFVS in order for the aircraft to proceed to a landing.

**d. EFVS Limitations.** During some reduced visibility conditions, an EFVS can display imagery that may significantly improve the pilot's capability to detect approach lights and visual references of the runway environment and aircraft, vehicles, and animals encroaching on the landing runway that may not otherwise be visible using natural vision. Pilots using an EFVS should be careful not to conclude that the flightpath is free of hazards merely because none are visible in the image. In some situations, imaging sensor performance can be variable and unpredictable. Additionally, in order to assure a safe obstacle clearance margin, certain nonprecision instrument approaches may require a pilot to visually identify known obstacles near the normal approach path when maneuvering in the visual phase for landing.

**e. Approach Minima.** Under current regulations there are two means of operating below DA or MDA from an IAP. One means is by using natural vision (§ 91.175(c)), and the other is by using an EFVS. Section 91.175(l) authorizes EFVS to be used below DA or MDA on straight-in IAPs other than CAT II or CAT III. The use of an EFVS, however, does not alter the minima for ceiling and flight visibility required for an IAP.

**f. Takeoff.** Takeoff at minima lower than that prescribed by the regulations must be approved on a case-by-case basis. For questions regarding takeoff at lower than prescribed minima, contact the Flight Standards Service (AFS), Flight Technologies and Procedures Division (AFS-400).

**g. Situation Awareness.** Use of an EFVS may improve safety by enhancing situation and position awareness, providing visual cues to maintain a stabilized approach, and minimizing missed approach situations. In addition to using an EFVS to satisfy requirements of § 91.175(l), an EFVS may allow the pilot to visually detect an obstruction on the runway, such as an aircraft or vehicle, earlier in the approach, and avoid potential runway incursions during ground operations in reduced visibility conditions. Even in situations where required flight visibility under § 91.175(c)(2) exists at the DA or MDA, an EFVS may provide useful visual cues for enhanced situation awareness.

## **9. EFVS OPERATIONS ON STRAIGHT-IN INSTRUMENT APPROACH PROCEDURES (OTHER THAN CAT II OR CAT III).**

**a. Basic Strategy Using EFVS.** When the runway environment cannot be visually acquired at DA or MDA using natural vision, a pilot may use an EFVS to continue descending down to 100 feet above the TDZE, provided all of the requirements of § 91.175(l) are met. The primary reference for maneuvering the aircraft is based on what the pilot sees through the EFVS. At 100 feet above the TDZE, a pilot can continue to descend only when the visual reference requirements for descent below 100 feet can be seen using natural vision. In other words, a pilot may not continue to rely on the EFVS sensor image to identify the required visual references below 100 feet above the TDZE. Here, the primary reference for maneuvering the aircraft is based on what the pilot sees with natural vision. Supporting information is provided by the FPV, FPA reference cue, onboard navigation system, and other imagery and flight symbology displayed on the EFVS. The FPV and FPA reference cue, along with the EFVS imagery of the TDZ, provide the primary vertical path reference for the pilot when vertical guidance from a precision approach or approach with vertical guidance is not available.

**(1) Straight-In Instrument Approach Procedures.** An EFVS may be used to descend below DA or MDA from any straight-in instrument approach procedure, other than CAT II or CAT III approaches, provided all of the requirements of § 91.175(l) are met. This includes straight-in precision approaches, approaches with vertical guidance (e.g., lateral approach procedures with vertical guidance (LPV) or lateral navigation (LNAV)/vertical navigation (VNAV)), and nonprecision approaches (e.g., VHF omni-directional range station (VOR), non-directional radio beacon (NDB), LOC, Area Navigation (RNAV), global positioning system (GPS), localizer-type directional aid (LDA), Simplified Directional Facility (SDF), etc.).

**(2) Circling Approach Procedure.** An instrument approach with a circle-to-land maneuver or circle-to-land minimums does not meet criteria for straight-in landing minimums. While the regulations do not prohibit EFVS from being used during any phase of flight, they do prohibit it from being used for operational credit on anything but a straight-in instrument approach procedure with straight-in landing minima. EFVS will only be used during a circle-to-land maneuver provided the visual references required throughout the circling maneuver are distinctly visible using natural vision. EFVS is permitted to be used to identify the required visual references in order to descend below DA or MDA on straight-in instrument approach procedures only. An EFVS cannot be used to satisfy the § 91.175(e)(2) requirement that an identifiable part of the airport be distinctly visible to the pilot during a circling maneuver at or above MDA or while descending below MDA from a circling maneuver.

**(3) Enhanced Flight Visibility.** Flight visibility is determined by using natural vision, and *enhanced* flight visibility is determined by using an EFVS. Section 91.175(l) requires that the *enhanced* flight visibility observed by using an EFVS cannot be less than the visibility prescribed in the instrument approach procedure to be used in order to continue to descend below the DA or MDA. This is analogous to the flight visibility requirement for natural vision in § 91.175(c).

**b. EFVS Operations At or Below DA or MDA Down To 100 Feet Above the TDZE.**

The visual segment of an instrument approach procedure begins at DA or MDA and continues to the runway. There are two means of operating in the visual segment—one is by using natural vision and the other is by using an EFVS. If the pilot determines that the *enhanced* flight visibility observed by using the EFVS is not less than the minimum visibility prescribed in the IAP being flown and the pilot acquires the required visual references prescribed in § 91.175(l)(3) using the EFVS, then the pilot can continue the approach to 100 feet above the TDZE. To continue the approach, the pilot uses the EFVS image to visually acquire the runway environment (the approach light system, if installed, or both the runway threshold and the TDZ), confirm lateral alignment, maneuver to the extended runway centerline earlier (higher and farther out from the runway) than would otherwise be possible, and continue a normal descent from the DA or MDA to 100 feet above the TDZE.

**(1) Required Visual References.** In order to descend below DA or MDA, the following visual references (specified in § 91.175(l)(3)) for the runway of intended landing must be distinctly visible and identifiable to the pilot using the enhanced flight vision system:

- (a) The approach light system (if installed), or
- (b) The following visual references in *both* (b)1. and (b)2. below:
  1. The runway threshold, identified by at least *one* of the following:
    - The beginning of the runway landing surface,
    - The threshold lights, or
    - The runway end identifier lights.
  2. The TDZ, identified by at least *one* of the following:
    - The runway TDZ landing surface,
    - The TDZ lights,
    - The TDZ markings, or
    - The runway lights.

**(2) Comparison of Visual Reference Requirements for EFVS and Natural Vision.** These visual reference requirements of § 91.175(l)(3) comprise a more stringent standard than

the visual reference requirements prescribed under § 91.175(c)(3) when using natural vision. The more stringent standard is needed because an EFVS might not display the color of the lights used to identify specific portions of the runway or might not be able to consistently display the runway markings. The main differences for EFVS operations are that the visual glide slope indicator (VGSI) lights cannot be used as a visual reference, and specific visual references from both the threshold and TDZ must be distinctly visible and identifiable. Under § 91.175(c)(3) using natural vision, however, only one of the specified visual references must be visible and identifiable.

**(3) Visual References and Offset Approaches.** U.S. Standard for Terminal Instrument Procedures (TERPS) criteria permits instrument approach procedures to be offset by prescribed amounts and still be considered straight-in with straight-in minima. A non-RNAV nonprecision approach, for example, can be offset up to 30 degrees from the runway centerline and be considered straight-in (have straight-in minima). A GPS or RNAV (GPS) approach with LNAV or LNAV/VNAV minimums can be offset as much as 15 degrees and still be considered straight-in, and an ILS approach can be offset as much as 3 degrees. Pilots must be especially knowledgeable of the approach conditions and approach course alignment when considering whether to rely on EFVS during a nonprecision approach with an offset final approach course. Depending upon the combination of crosswind correction (e.g., “crab”) and the lateral field of view provided by a particular EFVS, the required visual references may or may not be within the pilot’s view looking through the EFVS display. Many instrument approaches are constructed so that the final approach course (FAC) crosses the runway centerline extended well out from the runway. The FAC may cross as much as 5,200 feet from the landing threshold. With or without an approach light system, the required visual references may not be within the lateral view of the EFVS at MDA and may not come into view before the missed approach point is reached. Pilots conducting any nonprecision approach must verify lateral alignment with the runway centerline when determining when to descend from MDA. The actual lateral course alignment can vary depending upon the design of the instrument approach procedure, the facility type, distance from the facility, or the signal variations which can cause an offset from the intended course centerline.

**(4) When to Go Around.** Any pilot operating an aircraft with an EFVS installed should be aware that the requirements of § 91.175(c), using natural vision, and § 91.175(l), using EFVS, are different. A pilot would, therefore, first have to determine whether an approach will be commenced using natural vision in accordance with § 91.175(c) or using EFVS in accordance with § 91.175(l). While these two sets of requirements provide a parallel decisionmaking process, the requirements for when a missed approach must be executed differ. Using EFVS, a missed approach must be initiated at or below DA or MDA down to 100 feet above TDZE whenever the pilot determines that:

**(a)** The enhanced flight visibility is less than the visibility minima prescribed for the IAP being used;

**(b)** The required visual references for the runway of intended landing are no longer distinctly visible and identifiable to the pilot using the EFVS imagery (§ 91.175(l)(3));

(c) The aircraft is not continuously in a position from which a descent to a landing can be made on the intended runway, at a normal rate of descent, using normal maneuvers; or

(d) For parts 121 and 135 operators, the descent rate of the aircraft would not allow touchdown to occur within the TDZ of the runway of intended landing.

**(5) Missed Approach Considerations.** It should be noted that a missed approach after passing the DA, or beyond the missed approach point (MAP) involves additional risk until established on the published missed approach segment. Missed approach obstacle clearance is predicated on beginning the missed approach procedure at the DA or MAP and then climbing 200 feet/nm or greater. Initiating a go-around after passing the published MAP may result in loss of obstacle clearance. As with any approach, pilot planning should include contingencies between the published MAP and touchdown with reference to obstacle clearance, aircraft performance, and alternate escape plans. Paragraphs 9(e)(2) and (3) contain additional information about obstacle clearance as does the Aeronautical Information Manual (AIM) and the Instrument Procedures Handbook.

**c. EFVS Operations At and Below 100 Feet Above the TDZE.** At and below 100 feet above the TDZE, the regulations do not require the EFVS to be turned off or the display to be stowed in order to continue to a landing. A pilot may continue the approach below this altitude using an EFVS as long as the required visual references can be seen through the display using natural vision. An operator may not continue to descend beyond this point by relying solely on the sensor image displayed on the EFVS.

**(1) Required Visual References.**

(a) In order to descend below 100 feet above the TDZE the flight visibility—assessed using natural vision—must be sufficient for the following visual references to be distinctly visible and identifiable to the pilot without reliance on the EFVS to continue to a landing:

1. The lights or markings of the threshold, or
2. The lights or markings of the TDZ.

(b) It is important to note that from 100 feet above the TDZE and below, the flight visibility does not have to be equal to or greater than the visibility prescribed for the instrument approach procedure in order to continue descending. It only has to be sufficient for the visual references required by § 91.175(l)(4) to be distinctly visible and identifiable to the pilot without reliance on the EFVS. This differs from the requirements in § 91.175(c)(2) and (d)(2) where the flight visibility assessed by using natural vision cannot be less than the visibility prescribed by the instrument approach procedure being flown from DA or MDA all the way to touchdown.

**(2) Comparison of Visual Reference Requirements for EFVS and Natural Vision.** Again, the visual reference requirements for EFVS in § 91.175(l)(4) are more stringent than those required for natural vision in § 91.175(c)(3). The main differences for EFVS operations are that the approach light system and red terminating bars or red side row bars, the runway end identifier lights (REIL), and the Visual Approach Slope Indicator (VASI) cannot be used as

visual references. Only very specific visual references from the threshold or the TDZ can be used—the lights or markings of the threshold or the lights or markings of the TDZ.

**(3) When to Go Around.**

(a) A missed approach must be initiated when the pilot determines that:

1. The flight visibility is no longer sufficient to distinctly see and identify the visual references listed in § 91.175(1)(4) using natural vision,
2. The aircraft is not continuously in a position from which a descent to a landing can be made on the intended runway, at a normal rate of descent, using normal maneuvers; or
3. For parts 121 and 135 operators, the descent rate of the aircraft would not allow touchdown to occur within the TDZ of the runway of intended landing.

(b) While touchdown within the TDZ is not specifically addressed in the regulations for operators other than parts 121 and 135 operators, continued operations below DA or MDA where touchdown in the TDZ is not assured, where a high sink rate occurs, or where the decision to conduct a missed approach procedure is not executed in a timely manner, all create a significant risk to the operation.

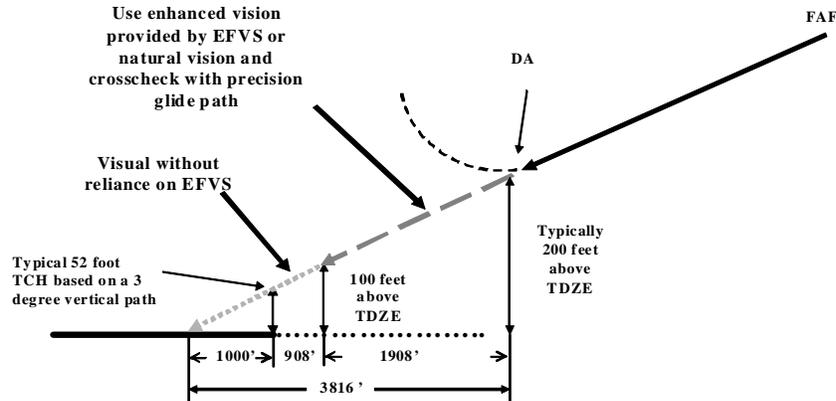
**(4) Missed Approach Considerations.** As noted before, a missed approach initiated after the DA or MAP involves additional risk. At 100 feet or less above the runway, it is likely that an aircraft is significantly below the TERPS missed approach obstacle clearance surface. Prior planning is recommended and should include contingencies between the published MAP and touchdown with reference to obstacle clearance, aircraft performance, and alternate escape plans. Paragraphs 9(e)(2) and (3) contain additional information about obstacle clearance as does the AIM and the Instrument Procedures Handbook.

**d. Example Flight Path Management Techniques Using EFVS.**

**(1) Example Precision Approach Using EFVS.** The pilot tracks the localizer and glideslope down to DA. At DA, the pilot makes a determination about whether the enhanced flight visibility is sufficient to continue the approach and whether the required visual references are distinctly visible and identifiable using the EFVS. From DA down to 100 feet above the TDZE, the primary reference for maneuvering the aircraft is based on what the pilot sees through the EFVS. This combination of sensor imagery and HUD flight symbology provides an accurate flight path reference that can be cross-checked below DA with localizer and glideslope information. From 100 feet above the TDZE down to the runway, the primary reference for maneuvering the aircraft is based on what the pilot sees with natural vision through the HUD along with HUD flight symbology. Continuing to cross-check localizer and glideslope information on a Category I (CAT I) ILS can provide useful information unless the instrument procedure has specific use limitations noted. Pilots must be aware that the CAT I glideslope signal is typically only flight inspected to 100 feet to support published minimums as low as 200 feet above the threshold. The localizer signal is only flight inspected for CAT I certification purposes to the missed approach point. Though many localizers provide acceptable guidance on

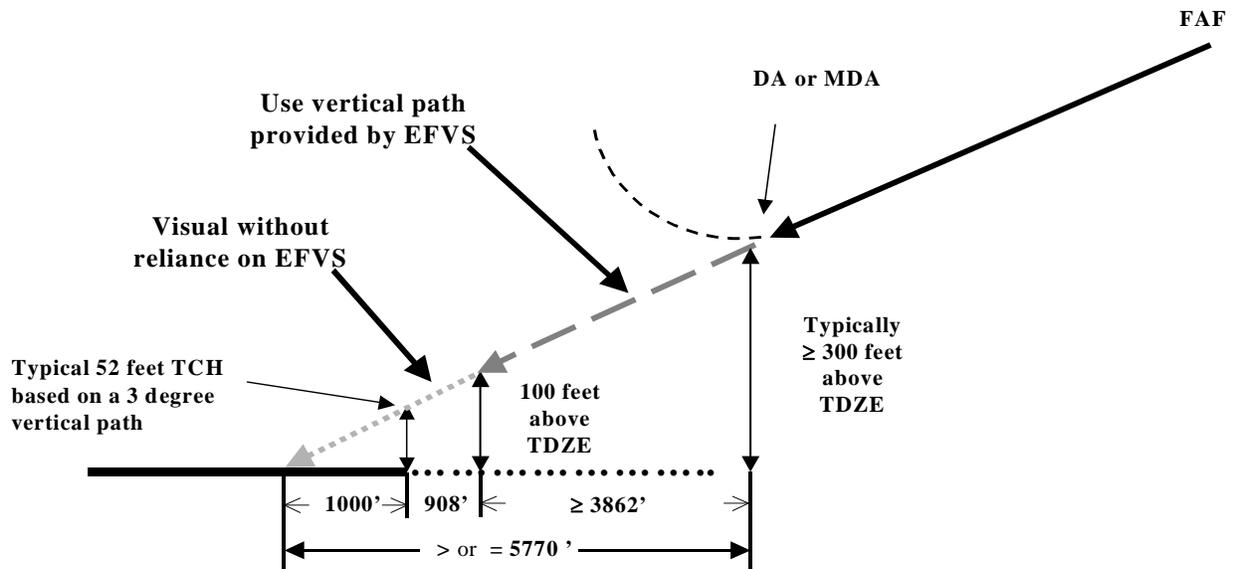
the runway, the necessary localizer critical area to ensure signal integrity is not maintained for CAT I ILS operations. For ILS critical area limitations, pilots should refer to the AIM paragraphs in Chapter 1, Section 1, titled “Instrument Landing System (ILS),” and the paragraphs in Chapter 2, Section 3, titled “Mandatory Instruction Signs” and “Location Signs.” A typical EFVS flight path management technique for precision approaches is shown in Figure 1, below.

**FIGURE 1. EFVS FLIGHT PATH MANAGEMENT TECHNIQUES – PRECISION APPROACH**



(2) **Example Nonprecision Approach Using VNAV.** The preferred method for conducting a nonprecision approach is to fly the aircraft on the vertical descent angle shown on the approach plate with deviation indications and guidance displayed on the HUD. The descent angle shown on the approach plate depicts a computed vertical path from the final approach fix (FAF) and altitude to the runway threshold at the published threshold crossing height (TCH). An example of this computed path is included in Figure 2. By using VNAV to track this path, the pilot maintains a stabilized approach.

**FIGURE 2. EFVS FLIGHT PATH MANAGEMENT TECHNIQUES – NONPRECISION APPROACH USING VNAV**



**(3) Example Nonprecision Approach Without VNAV.** To prevent controlled flight into terrain (CFIT) on nonprecision approaches, the FAA recommends a stabilized constant rate of descent that will safely clear all obstacles along the approach path. When VNAV is not available, another method for achieving a constant rate of descent should be used, such as using a self-computed descent rate or using a FPA reference cue to fly a vertical path that safely clears all obstacles.

**(a)** A constant-angle, constant-rate descent profile is the safest profile in all but special cases. On approaches for which no vertical guidance is available, the pilot should plan, execute, and monitor the approach with special care, considering wind conditions when choosing a target descent rate after the FAF. For two-pilot aircraft, to assure vertical clearance from terrain and obstacles and to promote situation awareness, the pilot monitoring the approach should announce crossing altitudes as published fixes and other points selected by the flightcrew are passed. The pilot flying (PF) should promptly adjust descent rate as appropriate.

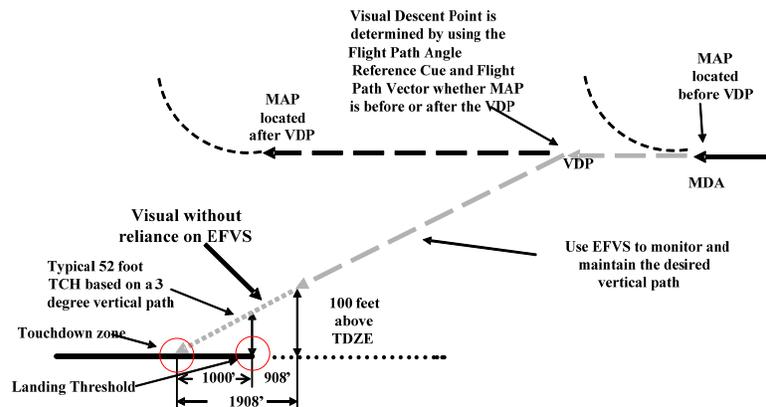
**(b)** For nonprecision approaches with no vertical guidance, the FPA reference cue and FPV may be used to position the aircraft on an appropriate descent angle to the TDZ. An example of the vertical path changes required for nonprecision approaches with no vertical guidance is shown in Figure 3, along with the technique for flying these approaches. An example of the FPV and FPA reference cues is shown in Figure 4. For these approaches, EFVS is used as follows:

*1.* When visual acquisition is attained by natural vision, the pilot should continue landing using normal techniques.

2. When visual acquisition is attained by EFVS alone, the pilot may continue the approach below MDA to 100 feet above the TDZE and should use the following techniques:

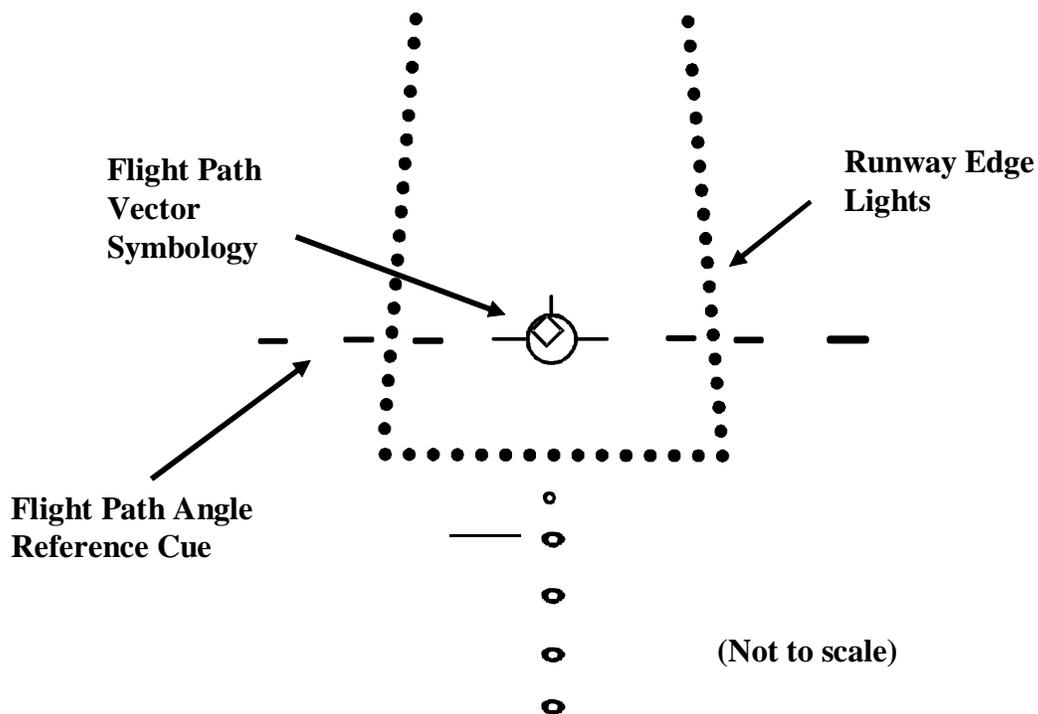
- Preset the FPA reference cue to a vertical descent angle consistent with the published IAP or the VGSI angle. If no vertical descent angle is published or if no VGSI is installed, preset the FPA reference cue to an angle calculated to clear obstacles.
- Continue at the MDA until the FPA reference cue is positioned over the desired touchdown point in the TDZ of the EFVS runway image.
- Adjust the descent rate of the aircraft until both the FPA reference cue is positioned over the desired touchdown point and the FPV is positioned over the FPA reference cue.

**FIGURE 3. EFVS FLIGHT PATH MANAGEMENT TECHNIQUES – NONPRECISION APPROACH WITHOUT VNAV**



**NOTE: Pilots conducting a nonprecision approach must verify lateral alignment with the runway centerline when determining when to descend from MDA. The actual lateral course alignment can vary depending upon the facility type, distance from the facility, or the signal variations which can cause an offset from the intended course centerline.**

FIGURE 4. FPA REFERENCE CUE



e. **Additional Considerations for Using EFVS Below DA or MDA.**

(1) **Stabilized Approach.** CFIT is one of the primary causes of aviation fatal accidents worldwide. Unstabilized approaches are a key contributor to CFIT events. Present non-precision approach design may require pilots to perform one or more “step-downs” during the final approach segment, necessitating multiple thrust, pitch and altitude adjustments inside the final approach fix, thereby increasing pilot workload and the potential for error during a critical phase of flight. Additionally, on approaches designed without “step-down” fixes, pilots may descend to the MDA immediately after the final approach fix. This practice, commonly referred to as “dive and drive,” can result in extended level flight as low as 250 feet above the ground in instrument meteorological conditions (IMC). The concept of a stabilized approach has been widely promoted for air carrier operators as a means to help eliminate approach and landing accidents. The goal is to have the aircraft in the proper landing configuration, at the proper approach speed, and on the proper flight path before descending below the minimum stabilized approach height. AC 120-71 (current edition) considers minimum stabilized approach height to be 1000 feet above the airport elevation or TDZE during IMC.

(2) **Visual Segment Obstacle Clearance.** Published approaches with vertical guidance (e.g., ILS/microwave landing system (MLS)) or computed vertical paths (e.g., LNAV/VNAV, LPV, etc.) provide the highest level of safety for both obstacle clearance and controlled rate of descent. If vertical guidance is not provided by the aircraft’s navigation systems, the use of the HUD’s FPV and FPA reference cue set to the published vertical descent angle on the instrument

procedure, VGSI angle, or where no angle is provided, an angle determined by the pilot to safely clear all obstacles, is recommended.

(a) The presence of a vertical descent angle (VDA) does not guarantee obstacle protection in the visual segment and does not change any of the requirements for flying a nonprecision approach. The published VDA is for information only, and is strictly advisory in nature. There is no implicit additional obstacle protection below the MDA. Approaches without visual descent points (VDP) have not been assessed for terrain or obstacle clearance below the MDA, and may not provide a clear vertical path to the runway at the normally expected descent angle. Therefore, pilots must be especially vigilant when descending below the MDA at locations without VDPs. This does not necessarily prevent flying the normal angle; it only means that obstacle clearance in the visual segment could be less and greater care should be exercised in looking for and avoiding obstacles in the visual segment.

(b) VDPs provide pilots with a reference for the optimal location to begin descent from the MDA, based on the designed VDA for the approach procedure, assuming the required visual references can be seen. Additional protection for the visual segment below the MDA is provided if a VDP is published and descent below the MDA is started at or after the VDP.

(c) Protection is also provided if a VGSI is installed and the aircraft remains within the lateral limits and vertical guidance provided by the VGSI from the MDA. In some cases, the VDA and VGSI angles are not coincident. When this is the case, a chart note will indicate that they are not coincident. Use of VGSI systems can aid the pilot in determining if the aircraft is in a position to make a descent from the MDA. However, when the visibility is close to minimums, the VGSI may not be visible at the start descent point for a normal glidepath, due to its location down the runway. In addition, current EFVSs are not capable of displaying color; therefore, glidepath information from the VGSI may not be usable when using EFVS alone.

(d) On RNAV approach charts, a small shaded arrowhead-shaped symbol (see the legend of the U.S. Terminal Procedures books, page H1) in the visual segment below DA or MDA to the runway indicates that the 34:1 slope is clear of obstacles. Absence of the shaded area on an RNAV approach indicates that the 34:1 slope is not clear of obstacles.

(e) Pilots should also exercise additional caution when a non-standard minimum visibility exists on an approach due to a penetration of the TERPS surfaces in the final approach segment or the obstacle clearance surfaces in the missed approach. When there are penetrations of these surfaces, the pilot must take precautions to avoid these obstacles when operating in the visual segment.

(f) Pilots are advised to carefully review approach procedures, prior to initiating an approach, to identify the optimum position(s), and any unacceptable positions, from which a descent to landing can be initiated. Additional information with respect to obstacle clearance, vertical descent angles, and visual descent points (VDP) can be found in the AIM and the Instrument Procedures Handbook.

**(3) Missed Approach Obstacle Clearance.** Missed approach obstacle clearance is predicated on beginning the missed approach procedure at the MAP, from MDA, or at the DA.

Some missed approach procedures require commencement of an immediate turn and/or climb of 200 ft/nm *or more* at the MAP. In these instances, initiating a go-around after passing the published MAP (for example, a balked landing) may result in loss of obstacle clearance because the aircraft flight path may not fall within the missed approach procedure protected area. To compensate for the possibility of reduced obstacle clearance during a balked landing/go-around, a pilot should consider the airport operating environment, including known natural (trees/vegetation) and man-made obstacles. At some airports, pilots may wish to refer to airport obstacle and departure data prior to initiating an IAP. Such information may be found in the "TAKE-OFF MINIMUMS AND (OBSTACLE) DEPARTURE PROCEDURES" section of the U.S. Terminal Procedures publication. Depending upon the airport operating environment, characteristics of the published missed approach procedure, overall aircraft performance capability, and other relevant considerations, pilots may wish to take one or more of the following actions after initiating a balked landing/go-around beyond the published MAP:

(a) Where practical, re-establish the aircraft laterally and vertically on the published missed approach procedure (for example, establish a straight-ahead climb, as rapidly as possible, may be all that is necessary to rejoin the missed approach segment; rejoining a turning missed approach may also be possible if the turn point has not yet been reached.).

(b) Adjust aircraft climb performance as necessary for the local environment (i.e., climb as rapidly as possible to avoid obstructions that were not a factor in the design of the published missed approach procedure).

(c) Maintain visual conditions, if possible, and return for landing, if practical.

(d) Where available, fly a published obstacle departure procedure (ODP) for the relevant runway.

(e) Comply with air traffic control (ATC) instructions when radar vectors have been issued or can be requested.

## **10. PILOT KNOWLEDGE, TRAINING, AND CHECKING.**

### **a. Pilot Knowledge for EFVS Operations.**

(1) Pilots should understand:

- The requirements of § 91.175;
- Those other regulations pertinent to the operation being conducted (e.g., §§ 121.651, 125.381, 135.225);
- Their OpSpecs/MSpecs/LOA, as applicable;
- The FSB report for the EFVS-equipped aircraft to be flown, if available;
- The EFVS Aircraft Flight Manual (AFM) system description, limitations, and procedures; and

- The guidance contained in this AC.

(2) Pilots operating an EFVS must be able to demonstrate knowledge and proficiency in the use of the equipment as required by the type of operation to be conducted.

**b. Pilot Training for EFVS Operations.** Knowledge and proficiency are key components of a successful instrument approach using an EFVS during reduced visibility conditions. Pilot training should be comprised of both ground and flight segments (simulated or actual) that are designed to meet the pilot knowledge recommendations of this AC. Persons providing EFVS training should follow the guidance provided in this AC. Operators should also refer to the FSB report for the EFVS-equipped aircraft they will be using, if available. Additional guidance is provided by the FAA NSP. FSB reports can be found at [www.opspecs.com](http://www.opspecs.com), and FAA NSP information can be found at: [http://www.faa.gov/safety/programs\\_initiatives/aircraft\\_aviation/nsp/](http://www.faa.gov/safety/programs_initiatives/aircraft_aviation/nsp/).

**(1) Pilot in Command (PIC) Training.** The FAA recommends each PIC of an aircraft equipped with an EFVS receive a minimum of 4 hours of initial ground training followed by a minimum of 2 hours of training in the left seat of an EFVS-equipped aircraft or a qualified flight simulator (see paragraph 10(b)(4)). The amount of training recommended is for a PIC already trained and proficient in the use of the aircraft's HUD. If the PIC is not trained and proficient in the use of the aircraft's HUD, the HUD training may be accomplished concurrently with EFVS training. Operators are responsible for training and checking each pilot who is flying aircraft equipped with EFVS in accordance with the training requirements of parts 121, 125, 135, and 91K (as applicable), the operator's approved or accepted training and checking programs, and the operator's OpSpecs, MSpecs, or LOA.

**(2) Second in Command (SIC) Training.** For aircraft that require more than one pilot or for flight operations where more than one pilot is required, the SIC should receive ground training which provides a complete understanding of the EFVS, its operation, and limitations. The SIC should also receive training in an aircraft or flight simulator to achieve proficiency on the callouts and crew coordination items associated with the use of the EFVS and repeater display, if installed.

**(3) Ground Training.** The FAA recommends ground training in the following areas:

**(a)** The specific sensor technology, sensor performance in varying weather conditions, sensor limitations, the sensor's ability to detect or not detect obstacles in the environment, and limitations where sensor performance can be variable and unpredictable.

**(b)** Weather associated with low ceilings and visibility.

**(c)** Regulatory requirements pertinent to the operation being conducted (e.g., §§ 91.175(l) and (m), 121.651, 125.381, 135.225).

**(d)** Enhanced flight visibility requirements (§ 91.175(l)(2)).

**(e)** Visual reference requirements (§ 91.175(l)(3) and (4)).

- (f) A review of the EFVS AFM system description, limitations, and procedures.
- (g) EFVS display, controls, modes, and associated systems, including the on/off switch “clear” mode.
- (h) EFVS operational considerations such as warm-up requirements, system alignment, display adjustments for brightness and contrast, contrast differences between daytime and nighttime approach conditions and display field of view.
- (i) Understanding and interpreting HUD symbology during EFVS operations.
- (j) EFVS system limitations, normal, abnormal, and emergency procedures.
- (k) Proper use of aircraft flight directors, autopilots, including any autopilot minimum use height considerations, and altitude alerting systems during EFVS operations.
- (l) Use of barometric and/or radio altitude at low heights, including temperature correction if applicable.
- (m) Use of the FPV and FPA reference cues.
- (n) Use and limitations of supplementary or advisory vertical information for situation awareness below DA or MDA.
- (o) Effect of crosswinds on EFVS field of view, including the use of caged and uncaged modes (if applicable) in crosswind conditions.
- (p) Crew briefings, procedures, callouts, and coordination items for EFVS operations, including annunciation of published minima and operation below the DA or MDA.
- (q) Duties of the PF and the PM during EFVS operations, as applicable.
- (r) Runway and approach lighting systems, including the effect of light-emitting diode (LED) lights on EFVS.
- (s) Instrument approach procedure considerations:
  1. Use of EFVS on precision approaches, approaches with vertical guidance, and nonprecision approaches.
  2. Effects of various approach types on aircraft alignment with the runway at DA or MDA during EFVS operations.
  3. Understanding of published VDAs, published VDPs, operator-calculated VDPs for descent below MDA, VGSI angles, and the significance of VDA and VGSI angles that are not coincident.
  4. Obstacle clearance awareness, including the potential for close-in obstacles on nonprecision approaches with no published VDP.

(t) Transition from EFVS imagery to non-EFVS natural vision and recognition of required visual references.

(u) Importance of cross-checking the HUD instrumentation presentations against the EFVS sensor image to enable the pilot to recognize malfunctions of the navigation equipment or improper presentation of elements in the visual scene during the approach.

(v) Visual anomalies such as “noise,” “blooming,” parallax, thermal crossover, and other visual effects.

(w) Normal and rejected landings, including loss of visual cues from the runway, TDZ, and rollout area.

(x) Runway incursion detection.

(y) Missed approach considerations below DA or MDA and after passing the MAP, including obstacle clearance awareness.

**(4) Aircraft or Flight Simulator Training.** The FAA recommends that EFVS training be accomplished in a flight simulator or an aircraft. If a flight simulator is used, training should be accomplished using a level C simulator, with a daylight visual display, or a level D simulator that has been qualified by the NSP for EFVS. The simulator EFVS visibility should be adjustable and set to realistic values when training. The flight or simulator training program should address the specifics of particular EFVS, based upon actual system capabilities. Training events should include the following, as applicable to the operations to be conducted:

(a) Importance of the “design eye position” in acquiring the proper EFVS image.

(b) EFVS setup and use of display, controls, modes, and associated systems, including adjustments for brightness and contrast under day and night conditions.

(c) Taxi and takeoff using EFVS.

(d) Precision approaches, approaches with vertical guidance, and nonprecision instrument approaches:

1. In day and night conditions.
2. Under various ceiling and low visibility conditions.
3. Using the FPV and FPA reference cues.
4. Using different approach lighting configurations.
5. Under various crosswind conditions.

6. In night visual flight rules (VFR) conditions to airports where there is a lack of on/off airport visual cues, no runway centerline lights, and no TDZ lights using the FPV and FPA reference cues (“black hole” approach).

7. Flown to flare, touchdown, and rollout.

(e) An IAP with up to 30 degrees offset flown to flare, touchdown and rollout under low visibility day and night conditions.

(f) Missed approach procedures flown from the MAP, from after passing the MAP, and from a 50-foot TCH.

(g) Determining enhanced flight visibility.

(h) Transition from EFVS sensor imagery to natural vision acquisition of the required visual references and the runway.

(i) Crew briefings, procedures, callouts, and coordination items for EFVS operations, including annunciation of published minima and operation below the DA or MDA.

(j) Use of on/off switch “clear” mode.

(k) Use of caged and uncaged modes in crosswind conditions.

(l) Use of the EFVS repeater display (if installed).

**c. Pilot Checking for EFVS Operations.** Checking generally consists of a proficiency check conducted in a level C simulator, with a daylight visual display, in a level D simulator that has been qualified by the NSP for EFVS, or on an EFVS-equipped aircraft. The proficiency check normally includes at least one instrument approach to published minimums and landing utilizing the EFVS. This check can be accomplished concurrently with a proficiency or competency check under §§ 61.57, 61.58, 121.441, 135.293, or 135.297.

(1) For parts 121, 125, and 135 certificate holders, the use of EFVS for operational credit is authorized for only those PICs and SICs who have completed the certificate holder’s approved EFVS training program and who have been qualified for EFVS operations by one of the certificate holder’s check airmen or an FAA inspector.

(2) For part 125 operators authorized to conduct operations in accordance with a LODA (LODA A125), the use of EFVS for operational credit is authorized for only those PICs and SICs who have completed EFVS training and who have been qualified for EFVS operations by a check airman or an FAA inspector.

(3) For part 91K operators, the use of EFVS for operational credit is authorized for only those PICs and SICs who have completed the program manager’s approved EFVS training program and who have been qualified for EFVS operations by one of the program manager’s check pilot or an FAA inspector.

(4) For foreign air carriers conducting operations in the United States under part 129, the use of EFVS for operational credit is authorized for only those PICs and SICs who have successfully completed the foreign air carrier’s EFVS training program and who have been certified as being qualified for EFVS operations by one of the foreign air carrier’s check airmen

(5) Persons conducting operations under part 91 (except for part 91K) are not required to receive training on the operation of EFVS. However, pilots are encouraged to obtain training on EFVS equipment and on those procedures applicable to the conduct of flight operations using EFVS.

**11. OPERATIONAL APPROVAL PROCESS FOR EFVS.** This section addresses operational approval for persons conducting EFVS operations under parts 91K, 121, 125, 129, and 135.

**a. Approval Process Overview.** The approval process is an orderly method used by Flight Standards inspectors to ensure that regulatory standards are met and safe operating practices are provided for. The process consists of five distinct yet related phases and can result in approving or not approving an operator's proposal. The following process is excerpted from guidance provided to FAA principal inspectors (PI) in FAA Order 8900.1, Flight Standards Information Management System (FSIMS), Volume 3, Chapter 1, and leads to formal operational approval. The process consists of the following five phases:

**(1) Phase One – Pre-Application.** Phase one of the approval process begins when an operator requests authorization from the FAA. The FAA and the operator must reach a common understanding of what the operator must do, what role the FAA will have, and what form, content, and documents are required for submission.

**(2) Phase Two – Formal Application.** Phase two begins when the operator submits a proposal to the FAA for formal evaluation. During this phase, the FAA reviews the operator's submission to ensure that the proposal is clearly defined and the documentation specified in phase one has been provided. The required information must be complete and detailed enough to permit a thorough evaluation of the operator's capability and competence to fully satisfy the applicable regulations, national policy, and safe operating practices. The PI facilitates coordination with the Aircraft Evaluation Group (AEG) and the Aircraft Certification Office (ACO), if necessary.

**(3) Phase Three – Document Compliance.** Phase three begins when the FAA starts its in-depth review and analysis of the operator's proposal. In this phase, the FAA evaluates the proposal to determine that it is not contrary to applicable FAA regulations, is not contrary to direction provided in other FAA guidance documents or other safety-related documents, and provides for safe operating practices. Planning for phase four also begins as the FAA starts to formulate plans to observe and evaluate the operator's ability to perform.

**(4) Phase Four – Demonstration and Inspection.** Phase four is the major validation phase of the process. In this phase, the FAA finalizes plans to observe and evaluate the operator's demonstration of its ability to perform in accordance with the procedures, guidelines, and parameters described in the formal proposal. Phase four is an operational evaluation of the operator's ability to function in accordance with the proposal evaluated in phase three. Phase four concludes when the operator provides sufficient proof to satisfy the FAA's requirements for meeting all the plan objectives or when the operator is unable to complete them satisfactorily.

**(5) Phase Five – Certification.** In phase five, the FAA approves the operator's proposal. If the proposal is not approved, the operator is notified in phase three or four. The operations inspector with oversight responsibility for the operator grants approval for the operational use of the EFVS through the issuance of OpSpecs, MSpecs, or an LOA.

**b. EFVS Operations Conducted Under Part 91 (Except for Part 91K).**

**(1)** While no specific operational approval (no letter of authorization) is required for part 91 operators (except for part 91K operators), it is strongly recommended that EFVS-specific training be accomplished and documented. Training may be provided by a part 141 or part 142 training facility or by an authorized instructor.

**(2)** Part 91 operators are reminded that EFVSs used to conduct operations under § 91.175(l) require an FAA type design approval (a TC, amended TC, or an STC), or for foreign registered aircraft, must comply with the EFVS equipment requirements of § 91.175(m). A field approval will not be used to install an EFVS that will be used to conduct EFVS operations under § 91.175(l). The AFM approved for the aircraft must contain EFVS provisions appropriate to the EFVS operations to be conducted, and maintenance, preventive maintenance, and alterations of EFVS equipment should be accomplished in accordance with the applicable provisions of parts 43 and 91.

**(3)** U.S. operators conducting EFVS operations outside the U.S. should inquire with the CAA of each country as to that State's equipment and operating requirements for EFVS.

**c. EFVS Operations Conducted Under Parts 91K, 121, 125, and 135.** An operational approval to use EFVS under § 91.175(l) is required for certificate holders, operators, and program managers conducting operations under parts 91K, 121, 125 (including part 125 LODA operators), and 135. Applicants should submit a request for operational approval to use an EFVS, along with supporting information and documentation, to the FAA certificate-holding district office (CHDO) or Flight Standards District Office (FSDO) responsible for that operator (see Figure 5).

**(1) Required Documents.** The major components of an EFVS application should include:

**(a)** Application letter.

**(b)** Description of aircraft and equipment proposed to be used for EFVS operations.

**(c)** Airworthiness documentation.

**(d)** AFM/Airplane Operations Manual (AOM)/Flight Operations Manual (FOM)/pilot's operating handbook (POH)/quick reference handbook (QRH) provisions for EFVS, as applicable.

**(e)** Minimum equipment list (MEL) and any proposed changes, if MEL relief for EFVS is sought.

(f) EFVS operating procedures – equipment, checklists, crew coordination and monitoring procedures, callouts, crew briefings, non-normal operations and procedures related to EFVS, and special environmental considerations, if any.

(g) Proposed flightcrew training program – PIC, SIC, ground, simulator, actual aircraft, initial, recurrent, upgrade, differences, and any other type of training that will be conducted.

(h) Maintenance program for EFVS equipment – maintenance procedures, procedures for approval for return to service, and EFVS-specific training for maintenance personnel.

(i) OpSpecs/MSpecs/LOA sought by the operator and any proposed amendments.

**(2) AFM/AOM/FOM/POH/QRH Provisions for EFVS.** The AFM/AOM/FOM/POH/QRH for the aircraft must contain EFVS provisions appropriate to the EFVS operations to be approved. EFVSs used to conduct operations under § 91.175(l) require an FAA type design approval (a TC, amended TC, or an STC), or for foreign registered aircraft, compliance with the EFVS equipment requirements of § 91.175(m). A field approval will not be used to install an EFVS that will be used to conduct EFVS operations under §§ 91.175(l), 121.651, 125.381, and 135.225.

**(3) Maintenance, Preventive Maintenance, and Alterations.** EFVS equipment should be maintained in accordance with the maintenance, preventive maintenance, and alteration rules applicable to the operator.

**(4) Issuance of OpSpecs, MSpecs, or LOA.** OpSpec C048 is required to be issued for operations conducted under parts 121, 125, and 135. LOA C048 is required to be issued to part 125 LODA operators. MSpec MC048 is required to be issued for operations conducted under part 91K. U.S. operators that meet applicable requirements for EFVS operations under §§ 91.175(l) and (m), 121.651, 125.381, and 135.225 may be authorized to conduct EFVS operations by issuance of C048, MC048, or LOA C048, as applicable. Before issuance, the FAA will verify:

(a) The EFVS equipment is installed in accordance with an FAA type design approval (TC, amended TC, or STC) for the make/model/series of aircraft (for U.S.-registered aircraft).

(b) The AFM/AOM/FOM/POH/QRH for the aircraft contain EFVS provisions appropriate to the EFVS operation to be authorized.

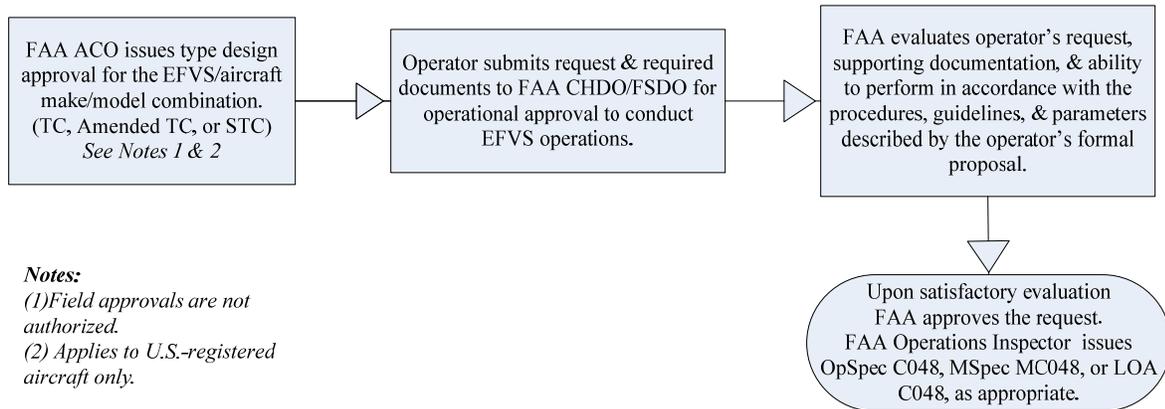
(c) The FAA has approved the MEL for the aircraft, if MEL relief for EFVS is sought (for U.S.-registered aircraft).

(d) The FAA has approved the EFVS training program for the flightcrew for EFVS operations conducted under parts 91K, 121, and 135.

(e) Part 125 operators have a training program for the flightcrew and that the training program for a part 125 operator without an LODA is approved.

(f) Maintenance provisions for EFVS equipment have been incorporated into the applicable maintenance programs for the operator.

**FIGURE 5. EFVS APPROVAL – PROCESS OVERVIEW FOR PERSONS INTENDING TO CONDUCT OPERATIONS UNDER PARTS 91K, 121, 125, AND 135.**



#### d. EFVS Operations Conducted Under Part 129.

(1) **Foreign Air Carrier Operations in the United States.** The general process used to obtain operational approval of an EFVS under § 91.175(l) and (m) is described below and illustrated in Figure 6. Additional guidance is provided below:

(a) **Required Documents.** The major components of an EFVS application should include:

1. Application letter.
2. Description of aircraft and equipment proposed to be used for EFVS operations.
3. Airworthiness documentation.
4. AFM provisions for EFVS.
5. MEL approval, including any EFVS provisions. (FAA approved MEL required for U.S. registered aircraft.)
6. EFVS operational approval issued by the State of the operator CAA.
7. EFVS training program approval issued by the State of the operator CAA.
8. Maintenance program approval, including EFVS provisions. (FAA approved maintenance program required for U.S. registered aircraft.)
9. OpSpecs and any proposed amendments sought by the operator.

**(b) AFM Provisions.** Foreign-registered aircraft used by a foreign air carrier for EFVS operations within the United States must have AFM provisions reflecting an appropriate level of EFVS capability that meets the display, features, and characteristics of § 91.175.

**(c) Additional Operational Credit for Previously Approved Systems.** When seeking additional operational credit each operator must apply the criteria addressed in the current version of this AC (e.g., EFVS HUD operations) or equivalent criteria acceptable to the FAA. Acceptable equivalent criteria are Joint Aviation Authorities (JAA) (European), European Aviation Safety Agency (EASA), or International Civil Aviation Organization (ICAO) criteria. Previous authorizations issued by the FAA that were based on criteria that existed at the time the authorization was issued remain in effect (e.g., HUD authorizations).

**(d) Maintenance Program Approval.** In accordance with § 129.14, “each foreign air carrier and each foreign person operating a U.S.-registered aircraft within or outside the United States in common carriage, will ensure that each aircraft is maintained in accordance with a program approved by the Administrator.” This maintenance program must contain maintenance provisions for EFVS equipment.

**(e) MEL Approval.** In accordance with § 129.14(b), no foreign air carrier or foreign person may operate a U.S.-registered aircraft with inoperable instruments or equipment unless a Master Minimum Equipment List (MMEL) exists for the aircraft type, and the foreign operator submits for review and approval its aircraft MEL, based on the MMEL, to the FAA. For EFVS operations, the EFVS system and components should be taken into consideration during MEL submission, review, and approval, if MEL relief for EFVS is sought.

**(f) Issuance of Part 129 OpSpecs.** Foreign air carriers operating to U.S. airports that meet applicable provisions above may be authorized to conduct EFVS operations through issuance of appropriate part 129 OpSpecs. Before issuing such OpSpecs to a foreign air carrier, the principal operations inspector (POI) will ensure that:

1. The EFVS equipment is installed in accordance with an FAA type design approval (TC, amended TC, or STC) for the make/model/series of aircraft; or for foreign-registered aircraft the EFVS equipment complies with all applicable U.S. EFVS equipment requirements; and any additional requirements established by the State of Registry of the aircraft, if applicable.

2. The aircraft approved AFM contains EFVS provisions appropriate to the EFVS operation authorized.

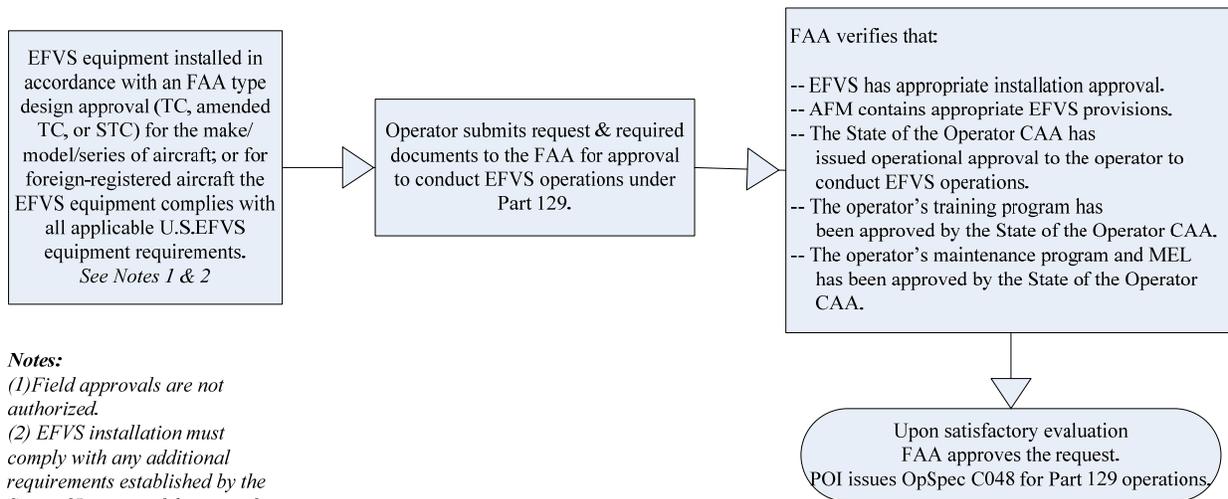
3. The CAA of the State of the operator has authorized/approved EFVS operations.

4. The CAA of the State of the operator has approved the maintenance program and MEL for the aircraft including EFVS provisions.

5. The carrier has an EFVS training program for flight crewmembers approved/authorized by the CAA of the State of the operator.

**NOTE: U.S. and foreign regulations with respect to EFVS operations may differ. Foreign air carriers operating aircraft under part 129 in the U.S. that expect to conduct all of the approach operations authorized by § 91.175(l) must provide training appropriate to the approach operations to be conducted.**

**FIGURE 6. EFVS APPROVAL – PROCESS OVERVIEW FOR FOREIGN AIR CARRIERS INTENDING TO CONDUCT OPERATIONS IN THE UNITED STATES**



**Notes:**

- (1) Field approvals are not authorized.
- (2) EFVS installation must comply with any additional requirements established by the State of Registry of the aircraft, if applicable.

**(2) Operations of U.S.-Registered Aircraft Solely Outside the United States.** EFVS operations conducted under part 129 in U.S.-registered aircraft solely outside the United States in common carriage by a foreign person or a foreign air carrier do not require operational approval; however, those operations must comply with those sections of part 129 specified in § 129.1(b).

**12. QUESTIONS AND COMMENTS.** Direct questions and comments regarding this AC to AFS-400 at (202) 385-4653.

ORIGINAL SIGNED by  
John McGraw for

John M. Allen  
Director, Flight Standards Service

**APPENDIX 1. ACRONYMS AND ABBREVIATIONS**

14 CFR	Title 14 of the Code of Federal Regulations
AC	Advisory Circular
ACO	Aircraft Certification Office
AEG	Aircraft Evaluation Group
AFM	Aircraft Flight Manual
AFS	Flight Standards Service
AIM	Aeronautical Information Manual
AOM	Airplane Operations Manual
ARP	Aerospace Recommended Practice
AS	Aerospace Standard
ATC	Air Traffic Control
CAA	Civil Aviation Authority
CAT I	Category I
CAT II	Category II
CAT III	Category III
CFIT	Controlled Flight into Terrain
CHDO	Certificate-Holding District Office
CHMB	Cockpit Head Motion Box
CMO	Certificate Management Office
CMU	Certificate Management Unit
CRM	Crew Resource Management
DA	Decision Altitude
DEP	Design Eye Position
DH	Decision Height

DME	Distance Measuring Equipment
EASA	European Aviation Safety Agency
ECO	Engine Certification Office
EFIS	Electronic Flight Instrument System
EFVS	Enhanced Flight Vision System
EVS	Enhanced Vision System
FAA	Federal Aviation Administration
FAC	Final Approach Course
FAF	Final Approach Fix
FFS	Full Flight Simulator
fL	Foot-Lambert
FLIR	Forward Looking Infrared
FMS	Flight Management System
FPA	Flight Path Angle
FPV	Flight Path Vector
FOM	Flight Operations Manual
FOV	Field of View
FSB	Flight Standardization Board
FSDO	Flight Standards District Office
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
GS	Glide Slope
HDD	Head-Down Display
HIC	Head Injury Criteria
HIRF	High Intensity Radiated Fields

HUD	Head-Up Display
IAP	Instrument Approach Procedure
ICAO	International Civil Aviation Organization
IFO	International Field Office
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
JAA	Joint Aviation Authorities (European)
LCD	Liquid Crystal Display
LDA	Localizer-Type Directional Aid
LED	Light-Emitting Diode
LNAV	Lateral Navigation
LOA	Letter of Authorization
LOC	Localizer
LODA	Letter of Deviation Authority
LPV	Localizer Performance with Vertical Guidance
MAP	Missed Approach Point
MDA	Minimum Descent Altitude
MLS	Microwave Landing System
MEL	Minimum Equipment List
MMEL	Master Minimum Equipment List
MSpec	Management Specification
NDB	Non-Directional Radio Beacon
NSP	National Simulator Program
ODP	Obstacle Departure Procedure

OpSpec	Operations Specification
PAI	Principal Avionics Inspector
PAPI	Precision Approach Path Indicator
PAR	Precision Approach Radar
PI	Principal Inspector
PIC	Pilot in Command
PF	Pilot Flying
PM	Pilot Monitoring
PMI	Principal Maintenance Inspector
POH	Pilot's Operating Handbook
POI	Principal Operations Inspector
QRH	Quick Reference Handbook
RCO	Rotorcraft Certification Office
REIL	Runway End Identifier Lights
RNAV	Area Navigation
SAE	Society of Automotive Engineers
SCO	Special Certification Office
SDF	Simplified Directional Facility
SIAP	Standard Instrument Approach Procedure
SIC	Second in Command
STC	Supplemental Type Certificate
SVS	Synthetic Vision System
TAWS	Terrain Awareness and Warning System
TC	Type Certificate
TCAS	Traffic Alert and Collision Avoidance System

TCH	Threshold Crossing Height
TDZ	Touchdown Zone
TDZE	Touchdown Zone Elevation
TERPS	U.S. Standard for Terminal Instrument Procedures
TSO	Technical Standard Order
VASI	Visual Approach Slope Indicator
VOR	Very High Frequency Omni-Directional Range Station
VDA	Vertical Descent Angle
VDP	Visual Descent Point
VFR	Visual Flight Rules
VGSI	Visual Glide Slope Indicator
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
VPATH	Vertical Path



## APPENDIX 2. DEFINITIONS

For the purpose of operations under this advisory circular (AC), the following definitions are provided:

- 1. Aircraft Certification Office (ACO).** The aircraft certification directorate's engineering operational element. This office administers and secures compliance with agency regulations, programs, standards, and procedures governing the type design of aircraft, aircraft engines, and propellers. The office offers certification expertise on investigating and reporting aircraft accidents, incidents, and service difficulties. The term "ACO" refers to an Engine Certification Office (ECO), the Rotorcraft Certification Office (RCO), the Special Certification Office (SCO), the Aircraft Certification Office (ACO), and all other ACOs.
- 2. Aircraft Evaluation Group (AEG).** A Flight Standards Service (AFS) field element that helps support the certification and operational suitability determinations of new and modified type-certificated products. AEGs are the primary AFS liaison between Flight Standards elements and the accountable aircraft certification directorate and/or the manufacturers. AEGs may be co-located with an accountable directorate or one of its elements.
- 3. Certificate-Holding District Office (CHDO).** A Federal Aviation Administration (FAA) Flight Standards District Office (FSDO), certificate management office (CMO), International Field Office (IFO), or Certificate Management Unit (CMU) assigned by the FAA to have oversight responsibility for a particular certificate holder.
- 4. Cockpit Head Motion Box (CHMB).** The portion of the eyebox from which the pilot can view all flight essential information.
- 5. Enhanced Flight Vision System (EFVS).** An electronic means to provide a display of the forward external scene topography (the natural or manmade features of a place or region especially in a way to show their relative positions and elevation) through the use of imaging sensors, such as a forward looking infrared (FLIR), millimeter wave radiometry, millimeter wave radar, or low light level image intensifying.
- 6. Enhanced Flight Visibility.** The average forward horizontal distance from the cockpit of an aircraft in flight at which prominent topographical objects may be clearly distinguished and identified by day or night by a pilot using an EFVS.
- 7. Enhanced Vision System (EVS).** An electronic means to provide the flightcrew with a sensor-derived or -enhanced image of the external scene (e.g., millimeter wave radar, FLIR).
- 8. Flight Standardization Board (FSB).** A designated group of operations inspectors who determine type rating, certification, and training requirements for new or modified aircraft.
- 9. Head-Up Display (HUD).** An aircraft system that provides head-up guidance to the pilot during flight. It includes the display element, sensors, computers, power supplies, indications, and controls. It may receive inputs from an airborne navigation system or flight guidance system. This system allows the pilot to look for the outside visual references in the same location as they appear in the EFVS image.

**10. Head-Down Display (HDD).** A display or suite of displays that provide control, performance, and navigation information that is presented to the pilot on conventional head-down instrumentation, or integrated electronic flight displays.

**11. Glide Slope.** Vertical guidance for an aircraft during approach and landing.

**12. Master Minimum Equipment List (MMEL).** A list of equipment that the FAA has determined may be inoperative under certain operational conditions and still provide an acceptable level of safety. The MMEL contains the conditions, limitations, and procedures required for operating the aircraft with these items inoperative. The MMEL is used as a starting point in the development and review of an individual operator's minimum equipment list (MEL).

**13. Minimum Equipment List (MEL).** The MEL is a list derived from the MMEL for a particular make and model of aircraft by an individual operator. The operator's MEL takes into consideration the operator's particular aircraft configurations, operating procedures, and conditions with certain inoperative equipment.

**14. Natural Vision.** The means by which a pilot observes objects without benefit of any vision-enhancing technology (except personal corrective lenses).

**15. Nonprecision Approach Procedure.** A standard instrument approach procedure (IAP) for which no electronic glideslope information is provided.

**16. Precision Approach Procedure.** A standard instrument approach procedure (SIAP) for which an electronic glideslope information is provided, such as instrument landing system (ILS) and precision approach radar (PAR).

**17. Special Instrument Approach Procedure.** An IAP authorized for use only by an air carrier or some other segment of the aviation industry that is not published in the Federal Register and identified as a "Special Procedure." Special Procedures may be developed for public or private use based on aircraft performance, aircraft equipment, or crew training, and may also require the use of landing aids, communications, or weather services not available for public use.

**18. Standard Instrument Approach Procedure (SIAP).** An IAP promulgated under Title 14 of the Code of Federal Regulations (14 CFR) part 97.

**19. Straight-In Nonprecision Approach.** An approved instrument approach procedure in which the final approach course alignment and descent gradient permits authorization of straight-in landing minima. The angle of convergence of the final approach course and the extended runway centerline will not exceed 30 degrees (15 degrees for Area Navigation (RNAV)/global positioning system (GPS)) and the point of intersection will normally be within 5,200 feet outward from the runway threshold. The maximum descent gradient is 400 ft/NM.

**20. Straight-In Precision Approach.** An approved IAP in which the final approach course alignment does not exceed 3 degrees of the extended runway centerline.

**21. Supplemental Type Certificate (STC).** An STC is issued for a major design change to a type certificate (TC) when the change is not so extensive as to require application for a new TC, except that the holder of a TC for a product may apply for amendment of the original TC.

**22. Synthetic Vision.** A computer-generated image of the external scene topography from the perspective of the flightdeck that is derived from aircraft attitude, high-precision navigation solution, database of terrain, obstacles, and relevant cultural features.

**23. Synthetic Vision System (SVS).** A system used to create a computer-generated image of the external scene topography from the perspective of the flightdeck. An SVS is comprised, in part, of a database component, a precise navigation component, instrument data interfaces, and a processing component that computes and “draws” the forward view based on what the external view should be if the database and navigation components are valid. An SVS display does not provide an independent, real-time source of forward scene information. An SVS using a HUD is not an EFVS and is not authorized as an alternative means of complying with § 91.175(l)(2) for descending below Decision Altitude (DA)/decision height (DH) or minimum descent altitude (MDA).

**24. Type Certificate (TC).** A design approval that certifies that an applicant’s design for a new (or new model) aircraft, engine, or propeller meets the minimum FAA requirements. It includes the type design, the operating limitations, the type certificate data sheet, the applicable regulations the type design was certified to, and any other conditions or limitations required in 14 CFR, Subchapter C.

**25. Touchdown Zone (TDZ) Elevation (TDZE).** The highest elevation in the first 3,000 feet of the landing surface. TDZE is indicated on the IAP chart when straight-in landing minimums are authorized.



### **APPENDIX 3. GUIDANCE ON AIRWORTHINESS CERTIFICATION FOR INSTALLATIONS OF ENHANCED FLIGHT VISION SYSTEM (EFVS) IMAGING SYSTEMS**

This appendix contains guidance for the airworthiness certification of an enhanced flight vision system (EFVS) imaging system. Mandatory terms used in this appendix such as “shall” or “must” are used only in the sense of ensuring applicability of these particular methods of compliance when the acceptable means of compliance described herein is used. This appendix does not change, add, or delete regulatory requirements, or authorize deviations from regulatory requirements.

References to head-up display (HUD) and associated criteria are meant to apply to “equivalent displays” as well. However, at this time the actual form and characteristics of such displays are speculative and for them the criteria may be incomplete. The Federal Aviation Administration (FAA) may require a proof of concept and then establish additional airworthiness criteria for equivalent displays.

For EFVS designs with operationally significant mode changes, the modes should be indicated in the HUD.

#### **1. Display Characteristics.**

**a.** The EFVS sensor imagery and aircraft flight symbology (i.e., at least airspeed, vertical speed, aircraft attitude, heading, altitude, command guidance, path deviation indications, Flight Path Vector (FPV), and Flight Path Angle (FPA) reference cue) must be presented on a HUD, or an equivalent display, in such a way that they are clearly visible to the pilot flying (PF) in his or her normal position and line of vision, and looking forward along the flightpath (see Title 14 of the Code of Federal Regulations (14 CFR) part 91, § 91.175(m)(2)). The displayed EFVS imagery, attitude symbology, FPV, FPA reference cue, and other cues, which are referenced to this imagery and external scene topography, must be presented so that they are aligned with and scaled to the external view (see § 91.175(m)(2)(i)).

**b.** The FPV will be used in conjunction with the FPA reference cue, EFVS image of the runway, and the external view of the runway (when in view) to perform its intended function. The lateral component of the vector must be the instantaneous aircraft track over the ground, and must be displaced from the aircraft heading by the drift angle. The vertical component of the FPV must be the resultant of the vertical velocity (inertial, not barometric) and ground speed (not airspeed). The FAA prefers an inertially referenced FPV; however, an alternative design may be proposed if it can be shown to demonstrate equivalent performance. The use of EFVS below approach minimums must be as safe as a Category II (CAT II) integrated instrument landing system (ILS) approach. See the current edition of AC 120-29, Criteria for Approval of Category I and Category II Weather Minima for Approach, appendix 2, paragraph 6.2. In cases where the basic navigation guidance alone would lead to path deviations not consistent with CAT II performance, the pilot must be able detect the deviations and correct, as necessary, using the imagery and flight path symbology.

c. During the instrument approach the FPA reference cue must be displayed with the pitch scale selectable by the pilot to the desired descent angle. The FPA reference cue must be suitable for monitoring the vertical flightpath of the aircraft on approaches without vertical guidance (see § 91.175(m)(2)(ii)).

## 2. Image Characteristics.

a. **Resolution.** The HUD system video resolution specification must be shown by the applicant to provide adequate definition at the HUD for the pilot to be able to detect and identify the approach lighting system on approach, and the centerline, runway, and taxiway lights on the ground. The evaluation of EFVS resolution ability to image the approach light system/structure must be made at an altitude considerably above the minimum descent altitude (MDA) or decision height (DH) without atmospheric obscurations.

b. **Luminance.** The HUD video luminance must be adequate to display a minimum number of gray shades (i.e., detectable levels of luminance) to meet the intended function in the background luminance conditions that are representative of the environment in which the HUD and sensor system is intended to operate. The applicant must specify the maximum background luminance in which the HUD and sensor system is intended to operate and the minimum number of gray shades it needs to display.

c. **Contrast Variation.** The contrast ratio between sequential gray shades must be sufficient to make them detectable with appropriate HUD brightness and contrast settings, excluding the contribution of ambient background. See Society of Automotive Engineers (SAE) Quality Standard Identification (AS) 8055, Minimum Performance Standard for Airborne Headup Display, for appropriate minimum contrast ratios.

### d. Low Level Luminance.

(1) The HUD must be capable of providing a very dim, easily controllable image, free of background glow in areas not displaying information in night conditions.

(2) The image must be shown by demonstration in a dark ambient background (SAE AS 8055 recommends less than 0.34 cd/m<sup>2</sup> (0.1 foot-Lamberts (fL)), with symbols and peak white video appropriately adjusted (SAE AS 8055 recommends approximately 1.7 cd/m<sup>2</sup> (0.5 fL)). A minimum number of shades of gray specified by the applicant must be visible and the areas of the video that are blank must not be visible.

(3) The variation in intensity between any two points within 10 degrees of each other, or within the monocular field of vision must not be excessive when a flat-field signal is applied. SAE AS 8055 defines luminance uniformity, recommends a maximum variation of  $\pm 35$  percent, and provides an acceptable method of calculation.

(4) The EFVS imagery must have no display noise, local disturbances, or artifacts that detract from the use of the system in the absence of atmospheric obscurations. The EFVS image must not exhibit any objectionable flicker (defined by SAE AS 8055 as brightness variations at frequencies above 0.25 Hz) or jitter, (defined by SAE AS 8055 as positional oscillations at frequencies of greater than 0.25 Hz and amplitude greater than 0.6 mrad).

**e. Display Dynamics.**

(1) The system operation must not be adversely affected by aircraft maneuvering or changes in attitude encountered in normal operation.

(2) For those elements of the display that are normally in motion, any jitter, jerkiness, or ratcheting effect must be neither distracting nor objectionable. The image update rate must be no less than 15 Hz, regardless of the EFVS's intended function. EFVS images used for more than situational awareness, such as control tasks associated with approach guidance and maneuvering must have higher update rates, on the order of 30 Hz or more.

(3) Any lag (i.e., latency) introduced by the display system must be consistent with the aircraft control task associated with that parameter. In particular, display system lag (including the sensor) for attitude must not exceed a first order equivalent time constant of 100 milliseconds for aircraft with conventional control system response. For an EFVS image that is not used for a control task (i.e., for situational awareness only), a longer lag time may be found satisfactory, provided it is demonstrated not to be misleading or confusing to the pilot.

(4) For an EFVS image that would be used by the pilot below MDA/DH to 100 feet above touchdown zone (TDZ) elevation (TDZE) to monitor and maintain (i.e., control) the vertical path (VPATH), the first order equivalent time constant must not exceed 100 milliseconds. If the use of the EFVS under § 91.175(l) is to be limited to precision instrument approaches or approaches where vertical navigation (VNAV) is suitable down to 100 feet above TDZE, then a longer lag time may be found satisfactory, provided it is demonstrated not to be misleading or confusing to the pilot.

**f. Image Controls.**

(1) Controls for image and symbology display parameters such as brightness, sensor gain, and contrast must provide independent adjustment for the image and symbology. For parameters that need adjustment for changes in ambient light levels, and other dynamic environmental conditions, the adjustments must be automatic, unless it can be shown that a single manual setting is satisfactory for the duration of any instrument approach.

(2) When the brightness level is altered, the relative luminance of the imagery must vary smoothly. There will be no objectionable brightness transients when transitioning between manual and automatic control, if applicable.

**3. Installation.**

**a. Control Visibility and Accessibility.** For compliance with 14 CFR part 25, § 25.777, the EFVS display controls must be visible to, and within reach of, the pilot from any normal seated position. For compliance with §§ 25.777, 25.789, and 25.1301, the position and movement of the controls must not lead to inadvertent operation. As required by § 25.1381, the EFVS controls, except those located on the pilot's control wheel, must be adequately illuminated for all normal background lighting conditions, and must not create any objectionable reflections on the HUD or other flight instruments. Unless fixed illumination of the EFVS controls is shown to be

satisfactory under all lighting conditions, there should be a means to adjust the illumination. Similar requirements exist for compliance with 14 CFR parts 23, 27, and 29.

**b. Cockpit Integration.** To the greatest extent possible, the EFVS controls must be integrated with other controls, to minimize the crew workload associated with EFVS operation, and to ensure flightcrew awareness of engaged flight guidance modes.

#### **4. Guidance on Demonstration Requirements.**

**a.** The display characteristics described in this appendix will be evaluated in as many different types of weather conditions as possible until enough confidence is gained that any areas where interference could be encountered are identified. Testing will include as many of the conditions below as possible and will be listed in the flight test plan:

(1) Day and night visual flight rules (VFR) conditions over various topography (urban, rural, snow covered, etc.).

(2) Day and night instrument flight rules (IFR) conditions over various topography.

(3) Representative levels of rainfall.

(4) Representative levels of snowfall.

(5) Representative levels of fog.

(6) Haze.

(7) Representative sun angles.

(8) Representative airport lighting configurations.

(9) Representative airport/runway surface conditions (dry, wet, standing water, snow cover).

**b.** In order to determine the acceptability of display update rate and lag, an evaluation will be conducted in dynamic atmospheric (e.g., turbulence, gusts) and maneuvering conditions, with appropriate stability augmentation systems off, if applicable, unless the applicant seeks approval only with augmentation operative. Because the evaluation of the effects of the imagery is largely subjective, an appropriate number of FAA test pilots should fly and assess the system.

**c.** The EFVS must be demonstrated to show that the pilot may use it to satisfactorily conduct instrument approaches under the provisions of § 91.175(l):

(1) To assess that the enhanced flight visibility is adequate to continue the approach.

(2) To see and identify features of the landing threshold and the TDZ.

(3) To monitor and maintain the VPATH between DH/MDA and 100 feet above TDZE.

d. Test conditions should include day and night, visual meteorological conditions (VMC) and instrument meteorological conditions (IMC) cases. Each type of straight-in instrument approach for which the applicant seeks approval should be demonstrated (e.g., ILS, VNAV with decision altitude, nonprecision with visual descent point, and nonprecision without visual descent point). Each method of monitoring and maintaining the desired VPATH will be satisfactorily demonstrated.

## 5. Guidance on System Requirements.

a. To demonstrate compliance with §§ 25.1301, 25.1309, and 91.175(l) and (m), the EFVS system must be shown to perform its intended function for each operation and phase of flight for which it would be used. Similar requirements exist for compliance with parts 23, 27 and 29.

(1) The normal operation of the EFVS must not adversely affect, or be adversely affected by, other aircraft systems. Malfunctions of the EFVS that could cause display of misleading information must be annunciated and the misleading information removed. Below DH/MDA, any malfunction that causes misleading indications of airspeed, altitude, attitude, direction and flight path (e.g., guidance, flight path marker, image misalignment) is considered hazardous.

(2) The primary intended function of the EFVS is to conduct straight-in instrument approaches under the provisions of § 91.175(l). The pilot will use the EFVS for three primary tasks:

(a) To assess that the enhanced flight visibility is adequate to continue the approach.

(b) To see and identify features of the runway threshold and/or the TDZ.

(c) To monitor and maintain the VPATH between DH/MDA and 100 feet above TDZE.

b. The criticality of the EFVS's function to display imagery, including the potential to display misleading information, must be assessed according to § 25.1309 and applicable guidance for electronic displays and system safety, such as the current editions of AC 23.1309-1 and AC 25-11. All alleviating flightcrew actions that are considered in the EFVS safety analysis must be validated during testing for incorporation in the Aircraft Flight Manual (AFM) limitation section, procedures section, or for inclusion in type-specific training. Similar requirements exist for parts 23, 27, and 29.

c. The safety analysis must be conducted to show that the integrated system, consisting of the HUD components and other EFVS components, meet critical signal integrity requirements for the airplane, HUD, and EFVS. System and subsystem malfunctions that are not shown to be extremely improbable must be demonstrated in a simulation or in flight. The malfunction annunciation and fault detection schemes must demonstrate operation to the designed level of integrity. For the HUD component of the EFVS see Appendix 4 of this AC.

**NOTE: The FAA Aircraft Certification Office (ACO) will evaluate the safety analysis submitted by the applicant and make the compliance finding.**

**d.** The EFVS system must be shown to comply with acceptable high intensity radiated fields (HIRF) protection, electromagnetic interference, and system lightning protection criteria. Appropriate HIRF protection criteria are included in § 25.1317. Similar requirements are found in parts 23, 27, and 29. For older aircraft, HIRF protection criteria may be specified in special conditions. Lightning protection criteria are addressed by § 25.1316, which must be included in the certification basis for some type designs.

**6. HUD.** For the HUD component of the EFVS, see Appendix 4 of this AC.

## **APPENDIX 4. GUIDANCE ON AIRWORTHINESS CERTIFICATION FOR INSTALLATIONS OF EFVS HEAD-UP DISPLAYS**

This appendix contains guidance for airworthiness certification of the head-up display (HUD) component of an enhanced flight vision system (EFVS). Mandatory terms used in this appendix such as “shall” or “must” are used only in the sense of ensuring applicability of these particular methods of compliance when the acceptable means of compliance described herein is used. This appendix does not change, add, or delete regulatory requirements, or authorize deviations from regulatory requirements.

If the installation of the HUD component was previously approved on the same model aircraft in accordance to criteria equivalent to this appendix (e.g., per Federal Aviation Administration (FAA) means of compliance issue paper), then the compliance data for that approval may be used. The applicant must show that compliance with this criteria is not adversely affected when the HUD is integrated with the EFVS. References to HUD and associated criteria are meant to apply to “equivalent displays” as well. However, at this time the actual form and characteristics of such displays is speculative and for them the criteria may be incomplete. The FAA may require a proof of concept and then establish additional airworthiness criteria for equivalent displays.

For EFVS designs with operationally significant mode changes, the modes should be indicated in the HUD.

### **1. Display Characteristics.**

**a.** The HUD display must be evaluated under the guidelines contained in guidance applicable to the aircraft model the electronic display is being installed in. Examples include the current editions of Advisory Circular (AC) 25-11, Electronic Flight Deck Displays, for Title 14 of the Code of Federal Regulations (14 CFR) part 25 airplanes and AC 23.1311-1, Installation of Electronic Displays in Part 23 Airplanes, for 14 CFR part 23 airplanes. The monochrome HUD must adequately separate information and use distinctive coding of display parameters like symbol shape, size, and location to compensate for the lack of color (see AC 25-11, chapter 5, section 31e(3), Separating Information Visually). For those phases of flight where airworthiness certification is predicated on the use of the HUD, the HUD display must be evaluated relative to the guidance contained in AC 25-11, chapter 6, section 36, Organizing Electronic Display Information Elements. This guidance must also be considered for all flight phases where it can be reasonably expected that the pilot will operate primarily by reference to the HUD. Specific considerations are as follows:

**(1)** For dynamic flight phases, such as takeoff or go-around, the airspeed and altitude displays must be evaluated against the full guidance of AC 25-11, chapter 5, section 31(a), (b), and (c), including scale length, reference marks, and labeling, and chapter 6, section 36(b)(3), Arrangement-Basic T Information. The overriding consideration is that the scales must provide the pilot with a quick-glance (instant) sense of present speed and altitude for those flight phases where it cannot be reasonably expected for the pilot to transition to the head-down display (HDD), or to transfer control to the pilot monitoring (PM). Applicants should review 14 CFR parts 23, 27, and 29 for similar requirements.

(2) During the precision approach phase, HUD formats have been accepted that provide a digital-only display of airspeed and altitude. Acceptance of these displays has been predicated on the availability of compensating features that provide clear and distinct warning to the flightcrew when these and certain other parameters exceed well-defined tolerances around the nominal approach state (approach warn), and these warnings have associated procedures that require the termination of the approach.

(3) If a different display format is used for go-around than that used for the approach, then to ensure that appropriate information is displayed for the go-around and to minimize pilot workload, the format transition must occur automatically as a result of the normal go-around or missed approach procedure.

(4) Changes in the display format and primary flight data arrangement must be minimized to prevent confusion and to enhance the pilot's ability to interpret vital data.

b. To perform its intended function (see part 23, § 23.1301, part 25, § 25.1301, and corresponding sections for other 14 CFR parts applicable to the type of installation), the HUD must provide adequate information to permit instant evaluation of the aircraft's flight state and position during all applicable phases of flight. This display of information must be shown to be adequate for manually controlling the aircraft, and for monitoring the performance of the automatic flight control system. Use of the HUD for manual control of the aircraft and monitoring of the automatic flight control system must not require exceptional skill, excessive workload, or excessive reference to other flight displays.

(1) To avoid delays in the pilot's recognition and response to an engine failure, the HUD system must be shown adequate for aircraft control and guidance during an engine failure during any phase of flight where airworthiness approval is predicated on the use of the HUD, or where it can be reasonably expected that the pilot will operate primarily by reference to the HUD.

(2) To avoid a delay in the pilot's recognition and initial response, the HUD must provide adequate cues for the pilot to satisfactorily respond to unusual attitudes. The applicant should not assume that the pilot will continuously scan primary flight references on the instrument panel while using the HUD. The pilot must neither be required to nor prohibited from immediately transitioning to the primary flight references on the instrument panel once an unusual attitude is detected. The HUD display must be demonstrated for all foreseeable modes of upset, including crew mishandling, autopilot failure (including "slowovers"), and turbulence/gust encounters.

(3) The HUD system's adequacy for use while manually controlling the aircraft must be demonstrated and evaluated according to the rating levels outlined below. This task-oriented evaluation must consider all normal, abnormal, and emergency operations, with single failures and combinations of multiple failures not shown to be extremely improbable. The evaluation must be extended to all HUD display formats, unless use of specific formats is prohibited for specific phases of flight. The rating levels for this evaluation are:

(a) Satisfactory: full performance criteria may be met with routine pilot effort and attention.

**(b) Adequate:** adequate for continued safe flight and landing; full or specified reduced performance may be met, but with heightened pilot effort and attention.

**(c) Controllable:** inadequate for continued safe flight and landing, but controllable for return to a safe flight condition, safe flight envelope, and/or reconfiguration so that the handling qualities are at least adequate.

**(4)** The pilot workload and compensation is allowed to progressively vary with failure state, atmospheric disturbance level, and flight envelope. Specifically, within the normal flight envelope, ratings of “Adequate” are acceptable in moderate atmospheric disturbance for probable failures, and in light atmospheric disturbance for improbable failures.

**c.** For those phases of flight where airworthiness certification is predicated on the use of the HUD, or when it can be reasonably expected that the pilot will operate primarily by reference to the HUD, the HUD should always display attitude (artificial horizon, bank angle, and pitch angle), airspeed (including mach number, if required for the airplane), barometric altitude, slip/skid, gyroscopically stabilized heading, and vertical speed. These requirements pertain to part 25 aircraft. Refer to parts 23, 27, and 29 for requirements applicable to other than transport category aircraft.

**d.** For instrument approaches, the HUD must also display radio altitude, vertical and lateral path deviation (e.g., glide slope, localizer), visual marker annunciation, distance measuring equipment (DME) readout, selected navigation source (such as instrument landing system (ILS-1), VHF omni-directional range station/distance measuring equipment (VOR/DME), flight management system (FMS), etc.), and flight director, as applicable. The applicant should note that operational approval requires that the reference scale (e.g., dots) be displayed for the glideslope and localizer. These requirements pertain to part 25 aircraft. Refer to parts 23, 27, and 29 for requirements applicable to other than transport category aircraft.

**e.** As with other electronic flight displays, the HUD airspeed indications do not typically show the entire range of airspeed. Section 25.1541(a)(2) states: “The airplane must contain - Any additional information, instrument markings, and placards required for the safe operation if there are unusual design, operating, or handling characteristics.” Similar regulations apply to aircraft certificated under parts 23, 27, and 29.

**(1)** FAA policy states that the airspeed indications provide pilots the equivalent “quick-glance” airspeed awareness that has been intrinsic on traditional mechanical round dial indicators. For part 25 applications, see FAA policy memoranda PS-ANM100-1992-00057, dated February 25, 1992, and PS-ANM100-1996-00056, dated September 12, 1996.

**(2)** Low speed awareness cues must provide adequate warning to the pilot that the airspeed is below the reference operating speed for the aircraft configuration (i.e., weight, flap setting, landing gear position, etc.); similarly, high speed awareness cues must provide adequate warning to the pilot that the airspeed is approaching an established upper limit that may result in a hazardous operating condition.

**(3)** The cues should be readily distinguishable from other markings such as V-speeds and speed targets (bugs). The cues must indicate not only the boundary value of speed limit, but

must clearly distinguish between the normal speed range and the unsafe speed range beyond those limiting values. Cross-hatching may be acceptable to provide delineation between zones of different meaning.

(4) The display requirements for airspeed awareness cues are in addition to other alerts associated with exceeding high and low speed limits, such as the stick shaker and aural overspeed warning.

f. For those phases of flight where airworthiness certification is predicated on the use of the HUD, or when it can be reasonably expected that the pilot will operate primarily by reference to the HUD, the current mode of the flight guidance/automatic flight control system must be clearly annunciated in the HUD, unless another location in close proximity to the HUD is shown to be equivalently conspicuous. Likewise, other essential information and alerts that may require immediate pilot action must be displayed for instant recognition. Such information includes malfunctions of primary data sources, guidance and control systems, or excessive deviations that require a go-around.

g. For those phases of flight where airworthiness certification is predicated on the use of the HUD, or when it can be reasonably expected that the pilot will operate primarily by reference to the HUD, such use must not cause a delay in the pilot's performance of immediate safety-related actions required in response to warnings.

(1) Since the transition from the HUD to the head-down instruments would delay the pilot's immediate intervention, there must be no event that requires the pilot to make an immediate transition from the HUD to the HDD in order to perform an immediately required action (e.g., response to a warning, initiate a missed approach), except for loss of the HUD system itself.

(2) Certain alerts and guidance information, which are displayed head down to support immediate pilot intervention, must be displayed on the HUD. For example, if a wind shear detection system, a ground proximity warning system (GPWS) or Terrain Awareness and Warning System (TAWS), a Traffic Alert and Collision Avoidance System (TCAS), or go-around guidance flight director mode is installed, it is essential that the guidance, warnings, and annunciations that are required to support pilot intervention by display in the pilot's primary field of view (FOV), also be displayed on the HUD.

**NOTE: The pilot's eyes are focused at virtual infinity while using the HUD. Therefore, guidance and alphanumeric information provided by these systems, which is intended to be in the pilot's primary FOV in accordance with their type design, must be displayed on the HUD. When warning and caution lights are used, they must be visible and conspicuous in the forward FOV of the pilot using the HUD.**

h. The content, arrangement, and format of the information must be sufficiently compatible with the HDD to preclude pilot confusion, misinterpretation, or excessive cognitive workload. Immediate transition between the two displays, whether required by navigation duties, failure conditions, unusual aircraft attitudes, or other reasons, must not present difficulties in data

interpretation or delays/interruptions in the crew's ability to manually control the aircraft or to monitor the automatic flight control system.

**i.** Events that may lead to transition between the HUD and the HDD must be identified and scenarios developed for evaluation. These scenarios must include systems failures and events leading to unusual attitudes. Transitions must be satisfactorily shown for all foreseeable modes of upset, including crew mishandling, autopilot failure (including "slowovers"), and turbulence/gust encounters.

**j.** The HUD display must present all information in a clear and unambiguous manner. For compliance with applicable sections of 14 CFR, such as §§ 23.773, 25.773, etc., the HUD symbology must not excessively interfere with the pilot's forward view, ability to visually maneuver the airplane, acquire opposing traffic, and see the runway environment. For compliance with applicable portions of §§ 23.1301, 23.1303, 25.1301, or 25.1303, data elements of primary flight displays, which are required by the regulations or are essential or critical, must be displayed, regardless of the display mode. Similar requirements are found in parts 27 and 29.

**k.** For compliance with § 23.1301, 25.1301, 27.1301, or 29.1301, symbols must appear clean-shaped, clear, and explicit with no distracting visual effects, ambiguities, halo, stair stepping, flicker, or jitter.

**l.** For compliance with § 23.1301, 25.1301, 27.1301, or 29.1301 in all phases of flight, the HUD must update the positions and motions of primary control symbols with sufficient rates and latencies to support satisfactory manual control performance.

**m.** For a liquid crystal display (LCD) based HUD, consideration must be given to unique LCD characteristics that are described in Society of Automotive Engineers (SAE) Aerospace Recommended Practices (ARP) 4256A, Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft, and include:

(1) Matrix anomalies such as stair stepping, line width variation, and moiré pattern must not be distracting or misleading and must be assessed in static and dynamic conditions. (See ARP 4256A, section 4.1.3.)

(2) Lines of a specified luminance must appear uniform at all rotational or translational orientations of the line. Line width variation must not be readily apparent or cause distracting visual effects (e.g., visual "roping"). (See ARP 4256A, section 4.1.6.)

(3) Symbols must not have distracting gaps or geometric distortions. Any distortions must not exceed one half the local line width. (See ARP 4256A, section 4.1.7.)

(4) Symbology in motion must not have distracting jitter, jerkiness, or ratcheting effects. They must maintain luminance, contrast, line width and symbol quality characteristics independent of the rate of motion. (See ARP 4256A, section 4.1.9.)

(5) The response time of LCD pixel state changes must not be so long as to create erroneous interpretation or loss of displayed information due to artifacts such as smearing and loss of luminance. Image retention (a persisting undesired afterimage) must not be readily

(6) Gray scale control, when used for anti-aliasing or to provide luminance control, must be sufficient for its intended function. Its use must not cause apparent variations in line shape and quality. Deviations across the HUD FOV must be minimized to avoid misleading information. (See ARP 4256A, section 4.2.5.)

(7) Display defects (described in SAE ARP 4256A, sections 4.1.12 through 4.1.12.3) must not cause confusion, distraction, nor misinterpretation of the display. Inconspicuous and undetected loss of information or changes in symbol/character appearance could be misleading. Design considerations to mitigate adverse safety effects may include defect tolerant symbology and display formats. Such defects, especially those involving multiple failed-off pixels are not readily apparent to the pilot and a means to positively indicate such malfunctions to the pilot must be provided. Additionally, a manual means for the flightcrew to detect display defects using test patterns with all pixels on and all pixels off, in turn, may be useful to detect failed pixels and assess their operational effects. (See ARP 4256A, section 3.4.)

## **2. Guidance on Installation Requirements.**

### **a. HUD Display Controls.**

(1) To demonstrate compliance with applicable sections of 14 CFR, such as § 25.777, the HUD controls must be located to be visible to, and within reach of, the pilot from any normal seated position. To demonstrate compliance with §§ 25.777, 25.789, and 25.1301, the position and movement of the controls must not lead to inadvertent operation. To demonstrate compliance with § 25.1381, the HUD controls must be adequately illuminated for all normal background lighting conditions and must not create any objectionable reflections on the HUD or other flight instruments. Unless fixed illumination is satisfactory under all lighting conditions, there must be a means to adjust it. Similar requirements exist for compliance with parts 23, 27, and 29.

(2) To the greatest extent practicable, the HUD controls must be integrated with other controls, including the flight director, to minimize the crew workload associated with HUD operation and to ensure flightcrew awareness of engaged flight guidance modes.

**b. HUD Display Brightness.** The HUD display brightness is a key factor in the pilot's ability to use the display and to see through it to view the outside scene.

(1) The control and dynamic range of HUD brightness must provide suitable display readability in ambient lighting conditions from 0 foot-Lamberts (fL) to 10,000 fL. When certain extreme lighting conditions make use of the HUD impractical (for example, flying directly toward the setting sun), a suitable alternative head down flight display must be available for the crew to make a ready transition to the HDD.

(2) Background (ambient) lighting conditions can change quickly while the aircraft is maneuvering. To demonstrate compliance with §§ 25.773 and 25.1301, or similar regulations for part 23, 27, or 29, and to avoid high workload, an automatic brightness control must be provided,

unless it can be shown that a single manual setting is satisfactory for the duration of a high workload phase of flight (e.g., instrument approach).

(3) When the brightness level is altered, the relative luminance of each displayed symbol, character, or data must vary smoothly without allowing any information to become invisible while other data remains discernible.

(4) To demonstrate compliance with § 25.773, or similar regulations for part 23, 27, or 29, there should be no objectionable brightness transients when transitioning between manual and automatic control.

**c. Regulatory Compliance.** To demonstrate compliance with §§ 25.803, 25.1307, 25.1411, and 25.1447, or similar regulations for part 23, 27, or 29, the installation of the HUD system must:

(1) Not interfere with or restrict other installed equipment such as emergency oxygen masks, headsets, or microphones.

(2) Not adversely affect the emergency egress provisions for the flightcrew, or significantly interfere with crew access.

(3) Not hinder the crew's movement while conducting any required flight procedures.

**d. Avoiding Injury.** The HUD system must be designed and installed to prevent the possibility of pilot injury in the event of an accident or any other foreseeable circumstance such as turbulence encounter, hard landing, bird strike, etc. The installation of the HUD, including overhead unit and combiner, must comply with the head injury criteria (HIC) of § 25.562(c)(5). Additionally, the HUD installation must comply with the retention requirements of § 25.789(a) and occupant injury requirements of § 25.785(d) and (k). The applicant should review parts 23, 27, and 29 for similar requirements.

**NOTE: Section 25.562 applies only for airplanes with that regulation in their certification basis.**

**e. Glare.** To demonstrate compliance with § 25.773, the installation of the HUD system must not present the crew with any objectionable glare or reflection in any lighting conditions. This is equally applicable from glare or reflections visible on the HUD system itself, or that originating from the HUD system and visible in other areas such as the windshield. Similar requirements exist for compliance with parts 23, 27, and 29.

**f. System Combiner.** To demonstrate compliance with § 25.773, the installation of the HUD system must not significantly obstruct the pilot's external FOV with, or without, the combiner deployed. The external view requirements of § 25.773 must be retained with the combiner deployed. Similar requirements exist for compliance with parts 23, 27, and 29.

(1) The HUD system combiner must not create any objectionable distortion of the pilot's external view.

(2) The optical qualities (accommodation, luminance, and vergence) of the HUD must be uniform across the entire FOV. When viewed by both eyes from any off-center position within the eyebox, non-uniformities must not produce perceivable differences in binocular view.

**g. The HUD Design Eyebox.** The visibility of the HUD and the primary flight information it displays is paramount to the HUD's intended function as a flight reference display. The basic requirements for instrument arrangement and visibility found in §§ 25.1321, 25.773, and 25.777 apply to these devices. Applicants should review parts 23, 27, and 29 for similar requirements.

(1) Section 25.1321 requires that each flight instrument for use by any pilot be plainly visible at that pilot's station, with minimum practicable deviation from the normal position and forward line of vision. Similar requirements exist for compliance with parts 23, 27, and 29. AC 25.773-1 defines the Design Eye Position (DEP) as a single point, selected by the applicant, that meets the requirements of §§ 25.773 and 25.777. For airworthiness certification purposes, the DEP is the pilot's normal seated position, and fixed markers or other guides must be installed at each pilot station to enable the pilots to position themselves in their seats at the DEP for an optimum combination of outside visibility and instrument scan. Applicants should review parts 23, 27, and 29 for similar requirements.

(2) To demonstrate compliance with §§ 25.773 and 25.1301, the pilot must be able to view all of the flight essential information displayed in the HUD while located at the DEP. The optical characteristics of the HUD make the ability to fully view information on the combiner much more sensitive to the pilot's eye position than for displays on the instrument panel. Similar requirements exist for compliance with parts 23, 27, and 29.

(3) Additionally, the flight essential information must remain in view with the small, involuntary motions of the pilot's head around the DEP. HUD manufacturers typically define a three-dimensional viewing volume called the "eyebox" within which certain visual performance requirements are met, but may not always provide a view of all flight essential information. (see SAE ARP 5288).

(4) The Cockpit Head Motion Box (CHMB) is centered on the DEP and its minimum dimensions are:

- Lateral: 1.5 inches left and right from the DEP.
- Vertical: 1.0 inches up and down from the DEP.
- Longitudinal: 2.0 inches fore and aft from the DEP.

(a) When the HUD is a Primary Flight Display, when airworthiness certification is predicated on the use of the HUD, or when the pilot can be reasonably expected to operate primarily by reference to the HUD, larger minimum CHMB dimensions than those shown above may be necessary.

(b) In addition to meeting the minimum CHMB dimensions, described in paragraph (4), the HUD must provide adequate tolerance for variant head displacements, and for "relaxed" pilot sitting positions, commonly used during long flights. The location of the HUD

(5) The applicant must specify the minimum monocular FOV, which will include the center of the HUD FOV that provides a full display of the minimum required flight information. By definition, whenever at least one of the pilot's eyes is within the CHMB, the required flight information will be visible in the HUD. The lateral and vertical dimensions of the CHMB represent the total movement of a monocular viewing instrument (e.g., pilot's eye) with a ¼ in. (6.35 mm) entrance aperture (pupil). The eyebox longitudinal dimension represents the total fore-aft movement over which the requirement of this specification is met.

(6) The HUD installation must comply with §§ 25.1321, 25.773, and 25.777 at the DEP. The HUD installation must accommodate pilots from 5'2" to 6'3" tall, seated with seat belts fastened and positioned at the DEP. Similar requirements exist for compliance with parts 23, 27, and 29.

(7) HUD installations with overhead projectors must be evaluated for the potential of the pilot's head, while located within the CHMB, to partially block the optical path between the projector and the combiner, and prevent the display of some flight essential information, under any foreseeable conditions, including unusual attitudes.

(8) Operational suitability of the CHMB, the minimum monocular FOV, and specified set of minimum required flight information will be evaluated by the FAA.

### **3. Guidance on System Requirements.**

a. To demonstrate compliance with § 25.1301, the HUD system must perform its intended function as a primary flight display during all phases of flight for which its use may be approved. The normal operation of the HUD system cannot adversely affect, or be adversely affected by, other airplane systems. Similar requirements exist for compliance with parts 23, 27, and 29.

(1) Malfunctions of the HUD system that cause loss of all primary flight information, including that displayed on the HUD and head-down instrument panel, must be extremely improbable.

(2) To demonstrate compliance with § 25.1309, misleading guidance displayed on the HUD that is not detected and annunciated in a timely manner, and, if followed, may result in a catastrophic event during the landing and go-around phases of flight, must be extremely improbable for each operation. Similar requirements exist for compliance with parts 23, 27, and 29.

(3) For the takeoff guidance function, failures that may result in unsafe conditions must be detected and promptly annunciated to the pilot. The guidance must be removed, but the removal of guidance, alone, is not adequate annunciation.

(4) For failures that result in misleading takeoff guidance and cannot be detected and annunciated by the system, there must be outside visual references or other information readily visible during the takeoff that the pilot may use to detect the failures and mitigate their effects.

These failures must be identified. The ability of the pilot to detect them and mitigate their effects must be verified by analysis, flight-test, or both.

(5) The probability of the flight guidance system generating misleading information that could lead to an unsafe condition must be improbable when the flightcrew is alerted to the condition by suitable fault annunciation or by information from other independent sources available within the pilot's primary FOV.

b. The criticality of the HUD system's function to display flight and navigation data, including the potential to display misleading information, must be assessed under §§ 25.1309 and 25.1333, and current editions of AC 25-11, Chapter 4, Safety Aspects of Electronic Display Systems, and AC 25.1309-1, System Design and Analysis. All alleviating flightcrew actions that are considered in the HUD safety analysis must be validated during testing for incorporation in the aircraft flight manual procedures section or for inclusion in type-specific training. Similar requirements exist for compliance with parts 23, 27, and 29.

(1) For compliance with § 25.1309, the safety analysis must be conducted to show that the integrated system, consisting of the HUD components, sensors, ILS receivers, radio altimeter, airplane inertial reference unit or equivalent, and air data, meet critical signal integrity requirements for the airplane and HUD. The malfunction annunciation and fault detection schemes must demonstrate operation to the designed level of integrity. Similar requirements exist for compliance with parts 23, 27, and 29.

(2) If the HUD integrated system includes optional or variable system components, such as inertial reference units or flight management systems, all combinations and permutations of components for which approval is sought must be considered in the safety analysis.

c. The current edition of AC 25-11, chapter 4, section 21(e)(2) states that the display of misleading information on more than one primary flight display can be catastrophic. Similar guidance exists for part 23 projects in AC 23.1311-1 (current edition). The HUD system software that generates, displays, or affects the generation or display of primary flight information must be developed to level A requirements, as specified in RTCA Document DO-178B, "Software Considerations in Airborne Systems and Equipment Certification," or similar processes that provide equivalent product and compliance data. For part 23, AC 23.1309-1 contains the design assurance levels required for part 23 products.

(1) Monitoring software that is shown to have no ability to generate, display, or affect the generation or display of primary flight information, and has the capability to command shutdown of the HUD system, must be developed to no less rigor than that defined in level C, or criticality as determined by a safety assessment of the HUD system.

(2) Alternatively, the monitoring software may be developed to level A criteria and the information display software to level B or level C criteria, provided it can be shown, based on system and software architecture and other means, including redundancy, independence, partitioning, dissimilarity and other protection of software and hardware functions, that such a design provides an equivalent level of system integrity as would be provided by a level A HUD display system with a level B or level C (as required) monitoring function.

**d.** The HUD system must monitor the position of the combiner and provide a warning to the crew when the combiner position is such that conformal symbols are misaligned.

**e.** For the takeoff, approach, and go-around phases of flight where airworthiness certification is predicated on the use of the HUD, or for these and other phases of flight where it can be reasonably expected that the pilot will operate primarily by reference to the HUD, the HUD display should not be unusable or unstable for more than one second after the normally expected electrical bus transients due to a power transfer. Transfer to standby attitude or transfer of control of the aircraft to the other pilot cannot be reasonably accomplished under these conditions in a timely enough manner to prevent an unsafe condition.

**f.** The HUD system must be shown to comply with acceptable high intensity radiated fields protection criteria and system lightning protection criteria. Lightning protection criteria are addressed in § 25.1316.

**g.** The minimum system performance must be demonstrated in the environmental conditions and with the environmental measurement procedures set forth in RTCA DO-160E. SAE AS 8055, section 5, provides a suitable outline for the application of RTCA DO-160E demonstrations for head up displays and may be used for the EFVS.