U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: Airworthiness Approval of Enhanced Vision System, Synthetic Vision System, Combined Vision System, and Enhanced Flight Vision System Equipment

Date: 12/6/16
Initiated by: AIR-130
AC No: 20-167A

This advisory circular (AC) provides guidance for gaining airworthiness approval for enhanced and synthetic vision systems in aircraft. Specifically, it provides one acceptable means for complying with Title 14 of the Code of Federal Regulations (14 CFR) part 23, 25, 27, or 29 airworthiness regulations when installing a synthetic vision system (SVS), enhanced vision system (EVS), combined vision system (CVS), or enhanced flight vision system (EFVS) in an airplane or rotorcraft.

Since the release of Draft AC 20-167A for public comment, the FAA revised the standard format for Advisory Circulars. AC 20-167A is formatted in compliance with the new standard format, meaning the numbering of paragraphs changed from the draft that was presented for public comment. The preamble accompanying the 2016 EFVS rule specifically references paragraphs 4-5, 4-5.c.4, 4-5.c.4.(h).(iv), and 6-2.f.4. These referenced paragraphs equate to paragraphs 4.5, 4.5.3.4, 4.5.3.4.8.4, 6.2.6.4, respectively.

If you have suggestions for improving this AC, you may use the Advisory Circular Feedback form at the end of this AC.

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CHAPTER 1. INTRODUCTION

1.1 Purpose

1.1.1 In this advisory circular (AC), the Federal Aviation Administration (FAA) provides guidance on airworthiness approvals of enhanced vision system (EVS), synthetic vision system (SVS), combined vision system (CVS), and enhanced flight vision system (EFVS) equipment installation. The FAA has attempted to use regulatory language that is performance based and not limited to a specific sensor technology. The FAA believes this action will accommodate future growth in sensor technologies used in vision systems.

1.1.2 Existing ACs address flight guidance symbology, head-up displays (HUD) and visual display characteristics (for example, AC 25-11B, *Electronic Flight Deck Displays*, AC 25.1329-1B, *Approval of Flight Guidance Systems* and AC 23.1311-1C *Installation of Electronic Display in Part 23 Airplanes*). For a complete listing of related regulations and guidance, refer to Appendix A and Appendix J. This AC complements existing guidance.

1.1.3 This AC is not mandatory and does not constitute a regulation. This AC describes an acceptable means, but not the only means, to install and obtain airworthiness approval for enhanced and synthetic vision technologies. However, if you use the means described in this AC, you must follow it in all aspects.

1.2 Audience

This AC is for airplane and rotorcraft manufacturers, modifiers, and type certification engineers seeking certification or installation guidance for their visual display system. Sections 23.773, 25.773, 27.773 and 29.773 address vision systems using a transparent display surface located in the pilot's outside view, such as a head-up-display, head-mounted display, or other equivalent display. Such "vision systems" could include any EVS, EFVS, SVS, or CVS.

1.3 Applicability

1.3.1 This AC applies to all applicants for a new type certificate (TC), an amended type certificate (ATC), or a supplemental type certificate (STC), to install enhanced and/or synthetic vision systems and equipment. The method of compliance described in this AC can be used to obtain a TC, STC, or ATC for an airplane or rotorcraft equipped with SVS, EVS, CVS, or EFVS equipment.

1.3.2 This AC does not address operational aspects of vision systems or any changes in aircraft operational capability that may result from installation of vision systems. Guidance material for the operational aspects of EFVS described in this AC can be found in AC 90-106A, *Enhanced Flight Vision Systems*.

1.4 How to Use This Document

1.4.1 This AC provides methods, procedures, and practices acceptable to the FAA for complying with regulations. EFVS compliance references are listed in Appendix A.

1.4.2 This material does not alter regulatory requirements.

1.4.3 This AC describes system performance.

1.4.4 EFVS safety standards and sample flight test considerations for EFVS conducted to 100 feet height above runway touchdown zone elevation (EFVS Approach System) and for EFVS operations conducted to touchdown and rollout (EFVS Landing System) are in Appendices B, C, D, and E.

1.4.5 A sample flight manual supplement is outlined in Appendix F.

1.4.6 Appendix G addresses specific installation guidance for EVS and/or SVS on rotorcraft. Appendix H addresses additional part 23 considerations for situation awareness only.

1.5 Definitions and acronyms are in Appendix I.

1.5.1 Certain material within this AC is from RTCA/DO-315A, Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems, and Enhanced Flight Vision Systems. RTCA/DO-315A is copyrighted by RTCA, Inc. and used with permission. Purchase information is in Appendix J.

1.6 Cancellation

AC 20-167, Airworthiness Approval of Enhanced Vision System, Synthetic Vision System, Combined Vision System, and Enhanced Flight Vision System Equipment, dated June 22, 2010, is canceled.

CHAPTER 2. VISION SYSTEMS OVERVIEW

2.1 Enhanced Vision Systems

2.1.1 An EVS is an electronic means to provide a display of the forward external scene topography through the use of imaging sensors, such as forward looking infrared (FLIR), millimeter wave (MMW) radiometry, MMW radar, and/or low-light-level image intensifying. EVS need not provide the additional flight information/symbology required in 14 CFR 91.176 on a Head Up Display (HUD) or equivalent display. While Enhanced Vision Systems share a similarity with EFVS technology, an EVS does not have to be integrated with a flight guidance system. Furthermore, while an EVS may provide additional situation awareness without the additional capabilities provided by an EFVS, it provides no credit towards operations conducted under 14 CFR 91.176 (a) and (b). The elements of an installed EVS are listed below, with the EVS diagram shown in Figure 1:

- EVS sensor system.
- Display processor.
- EVS display.
- Pilot controls/interface.
- Mounting.

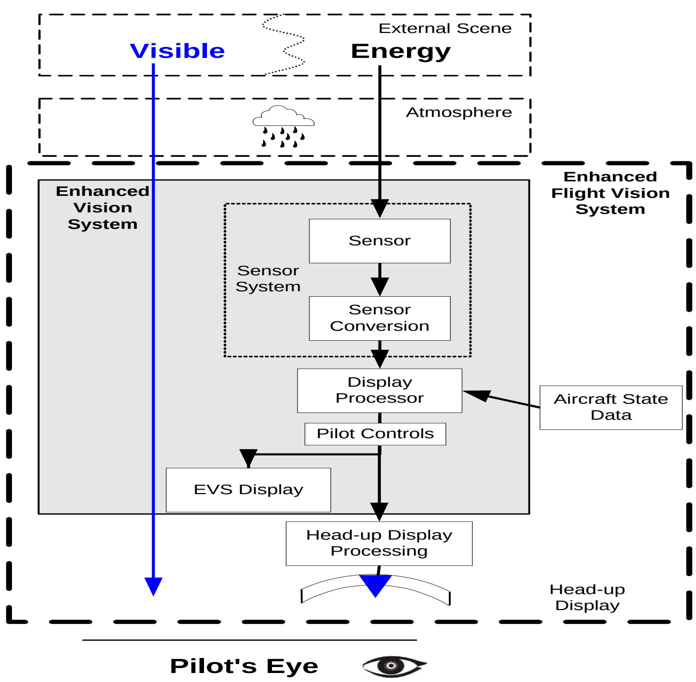

Figure 1. Enhanced Vision Diagram
(Dashed lines and shading represent individual system boundaries for EVS and EFVS)

Note 1: While an EFVS contains all the elements of an EVS, for the purposes of this AC any discussion of an EVS excludes an EFVS.

Note 2: For the purposes of this AC, any guidance that applies to Head Up Display (HUD) also applies to displays equivalent to HUD.

2.1.2 The categories of current EVS sensors are passive or active sensors.

2.1.2.1 Passive Sensors: Scene contrast detected by passive infrared sensors can be much different than that detected by natural pilot vision. On a dark night, thermal differences of objects, not detectable by the naked eye, will be easily detected by many imaging infrared systems. However, contrasting colors in visual wavelengths distinguished by the naked eye may not be visible using an imaging infrared system. Sufficient thermal scene contrast allows shapes and patterns of certain visual references to be recognized in the infrared image by the pilot. However, depending on conditions, they can also appear different to a pilot in the infrared image than they would with normal vision.

2.1.2.2 Active Sensors: Scene contrast by active systems depends on several parameters such as: whether the transmitter is centered on the aircraft velocity vector, display updates rates, latency, range resolution, sensitivity, dynamic range, and azimuth and elevation resolution. For an active infrared thermal imaging sensor, the infrared illuminator has the potential to illuminate more weather obscurations, which can compete with scene contrast and interpretation. One advantage of millimeter wave radar systems is their general immunity to weather obscurations.

2.1.2.3 Unlike the pilot's external view, the enhanced vision image can be a monochrome, two-dimensional display. Some, but not all, of the depth cues found in the natural view are also found in the imagery. The quality of the enhanced vision image and the level of enhanced vision sensor performance depend on the atmospheric and external visible and non-visible energy source conditions. Gain settings of the sensor, and brightness or contrast settings of the display, can significantly affect image quality. Certain system characteristics could create distracting and confusing display artifacts.

2.2 Synthetic Vision Systems

2.2.1 Synthetic vision is a computer-generated image of the external scene topography relative to the aircraft that is derived from aircraft attitude, high-precision navigation solution, and database of terrain, obstacles, and relevant cultural features. A synthetic vision system is an electronic means to display a synthetic vision image of the external scene topography to the flight crew. Synthetic vision creates an image relative to terrain and airport within the limits of the navigation source capabilities (position, altitude, heading, track, and the database limitations). SVS provides situation awareness but cannot be used in lieu of natural vision. The application of synthetic vision systems is through a primary flight display from the perspective of the flight deck (egocentric), or through a secondary flight display from the perspective correlating to outside the aircraft (exocentric, like a "bird's eye" view of a moving map display). This AC addresses both perspectives. The elements of an installed SVS are listed below, with the SVS diagram shown in Figure 2.

- Display (includes interface and installation).
- System interface.
- Database of terrain and obstacles.
- Sources providing the aircraft altitude, attitude, and position.

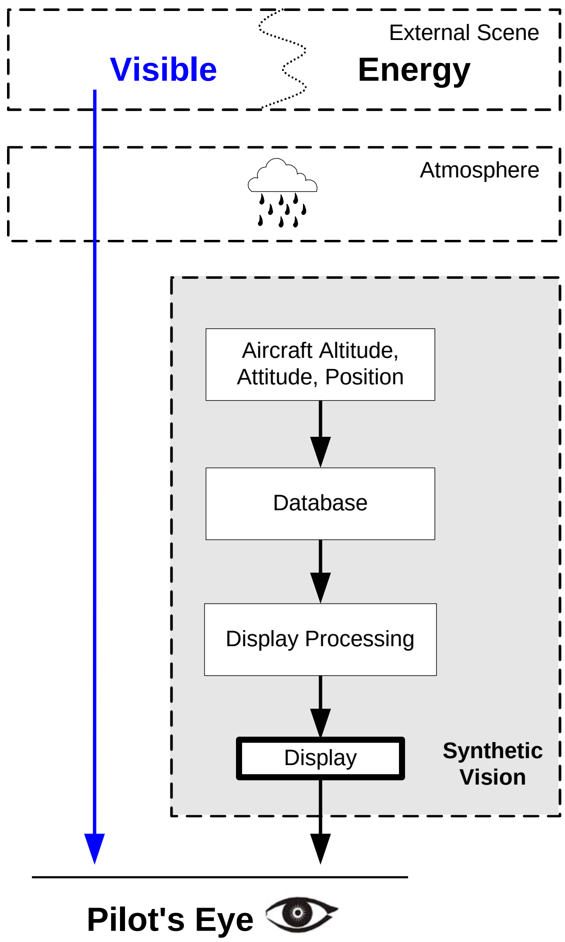

Figure 2. Synthetic Vision Diagram
(Dashed lines represent individual system boundaries. External scene visible image is not affected by SVS.)

2.2.2 Synthetic vision coordinate referenced databases are usually referenced to digital terrain elevation data (DTED). Digital terrain data can help produce a digital elevation model (DEM), a terrain database used to draw the terrain image on a synthetic vision display.

Note: For information purposes, there are three DTED levels with the following terrain spacing:

- DTED Level 0 uses 30 arc second spacing (nominally one kilometer).
- DTED Level 1 uses 3 arc second spacing (approximately 100 meters).
- DTED Level 2 uses one arc second spacing (approximately 30 meters).

2.2.3 With the exception of terrain and database processing (addressed in chapter 4, paragraph 4.3.7), synthetic vision characteristics may include:

2.2.3.1 Display factors, such as:

- Conformality.
- Refresh rate.
- Field of regard (FOR).
- Field of view (FOV).

2.2.3.2 Display placement factors, such as:

- Pilot's primary FOV versus pilot's secondary FOV. See figure A3-1 in AC 25-11B.
- Head down display (HDD) versus Head up display (HUD).

2.2.3.3 Terrain presentation factors, such as:

- Depiction (such as monochromatic, photo-realistic, elevation coloring).
- Gridding (presence versus absence, spacing).
- Color, shading, shadowing, and texturing. (This AC does not establish criteria for these items.)
- Resolution. DEM resolution and DTED level.
- Range indication (e.g., terrain based range marks, color scheme).

2.2.3.4 Terrain and cultural features, such as:

- Rivers, valleys, and mountains.
- Major landmarks, highways, and buildings within close proximity to airport.
- Hue and contrast between terrain and sky.

- Man-made obstacles (e.g., radio towers, bridges, tall buildings) and airport depiction.
- Airport depiction, including markings (e.g., extended runway centerline and numbers, taxiway markings, approach lighting system).
- Range marks or indications.

2.2.3.5 Functions, such as:

- Alerting (terrain, obstacles, traffic, and airspace).
- Declutter.
- Mode reversion.
- Image control (FOV, brightness, contrast, registration).

2.2.3.6 Integration of guidance symbology (if incorporated), such as:

- Guidance cues (flight path vector, flight path angle reference cue, velocity vector, command guidance cues, deviation indicators, and trend indicators).
- Aircraft reference relative to terrain (indication of relationship between zero pitch line and terrain).
- Pathway markings (“breadcrumbs,” rectangles) and boundaries, to indicate past or intended future aircraft track.
- Navigation information (course lines, fixes, icons, special-use airspace).
- Unusual attitude recovery.
- Crosswind indication (and image display based on cross-track).

2.3 Combined Vision Systems

2.3.1 The CVS concept involves a combination of SVS and EVS or EFVS. Some examples of a CVS include database-driven synthetic vision images combined with real-time sensor images superimposed and correlated on the same display. This includes selective blending of the two technologies based on the intended function of the vision system for which approval is sought. For example, on an approach, most of the arrival would utilize the SVS picture. As the aircraft nears the runway, the picture gradually and smoothly transitions from synthetic to enhanced vision, either for SVS picture validation or displaying the runway environment.

2.3.2 For combined vision systems applicants are expected to meet applicable performance criteria for each incorporated system.

2.4 Enhanced Flight Vision Systems

2.4.1 An EFVS, as defined in 14 CFR § 1.1, is "an installed aircraft system which uses 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, including but not limited to forward-looking infrared, millimeter wave radiometry, millimeter wave radar, or low-light level image intensification. An EFVS includes the display element, sensors, computers and power supplies, indications, and controls." The EFVS must present EFVS sensor imagery, aircraft flight information, and flight symbology on a head up display, or an equivalent display, so that the imagery, information and symbology are clearly visible to the pilot flying in his or her normal position with the line of vision looking forward along the flight path (ref 14 CFR § 91.176(a)(1)(i)(B)). During an instrument approach, the enhanced vision image is intended to enhance the pilot's ability to detect and identify the visual references required by the regulations.

2.4.2 An EFVS requires a real-time imaging sensor providing demonstrated vision performance in low visibility conditions and a level of safety suitable for the proposed operational procedure. This allows the required visual references to become visible in the image before they are visible naturally out-the-window. Depending on atmospheric conditions and the strength of energy emitted and/or reflected from the scene, the pilot can use the imagery produced by an EFVS to see these visual references on the display better than the pilot can see them through the window without enhanced vision. Currently approved enhanced flight vision systems use passive infrared sensor technology. However, an active or passive sensor, as described in chapter 2, paragraph 2.1.2, could be used provided it meets the performance criteria in this AC.

2.4.3 Depending on the intended operational function of the EFVS, airworthiness approval will be designated as an EFVS Approach System or EFVS Landing System as described below. Depending on the airworthiness approval being sought by the applicant, additional basic equipage may be required by § 91.176. Those additional requirements are discussed in paragraph 4.5 of this AC.

2.4.3.1 EFVS Approach System – The installed EFVS has been demonstrated to meet the criteria for AC 20-167A for an EFVS Approach System to be used for instrument approach operations from DA/DH or MDA to 100 TDZE while all system components are working, but may have failure modes that result in the loss of EFVS capability. Above 100 feet above the TDZE, the pilot is expected to conduct a go-around if the EFVS fails. Descent below 100 feet above the TDZE through touchdown and rollout is conducted using natural vision, so any failure of the EFVS should not prevent the pilot from completing the approach and landing.

2.4.3.2 EFVS Landing System – The installed EFVS has been demonstrated to meet the criteria for AC 20-167A for EFVS Landing System to be used for instrument approach and landing operations that rely on sufficient visibility conditions to enable unaided rollout and to mitigate for loss of

EFVS function. An EFVS that meets the certification criteria for EFVS Landing System also meets the certification criteria for an EFVS Approach System.

2.4.4 The basic elements of an installed EFVS are required by 14 CFR § 91.176(a)(1)(i), and are listed below, with the EFVS diagram in Figure 1. Specific system criteria for EFVS systems can be found in Chapter 4 of this AC.

2.4.4.1 The EFVS must have an electronic means to provide a display of the forward external scene topography (the applicable 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, including but not limited to forward-looking infrared, millimeter wave radiometry, millimeter wave radar, and low-light level image intensification;

2.4.4.2 Present EFVS sensor imagery, aircraft flight information, and flight symbology on a head up display, or an equivalent display, so that the imagery, information and symbology are clearly visible to the pilot flying in his or her normal position with the line of vision looking forward along the flight path. Aircraft flight information and flight symbology must consist of at least airspeed, vertical speed, aircraft attitude, heading, altitude, height above ground level such as that provided by a radio altimeter or other device capable of providing equivalent performance, command guidance as appropriate for the approach to be flown, path deviation indications, flight path vector, and flight path angle reference cue. Additionally, for aircraft other than rotorcraft, the EFVS must display flare prompt or flare guidance. The display should include:

2.4.4.2.1 The EFVS must present the displayed EFVS sensor imagery, attitude symbology, flight path vector, and flight path angle reference cue (FPARC), and other cues, which are referenced to the EFVS sensor imagery and external scene topography, so that they are aligned with and scaled to the external view;

2.4.4.2.2 The EFVS must display the flight path angle reference cue (FPARC) with a pitch scale. The FPARC must be selectable by the pilot to the desired descent angle for the approach and be sufficient to monitor the vertical flight path of the aircraft. The descent angle may also be automatically set to a value found in an onboard database.

2.4.4.2.3 The displayed sensor imagery, aircraft flight information, and flight symbology do not adversely obscure the pilot's outside view or field of view through the cockpit window.

2.4.4.3 The EFVS includes the display element, sensors, computers and power supplies, indications, and controls. It may receive inputs from an airborne navigation system or flight guidance system; and

2.4.4.4 The display characteristics, dynamics, and cues that are suitable for manual control of the aircraft.

2.4.4.5 Depending on the EFVS intended function, installations designed to be eligible for EFVS Landing System operations must also have a flare cue and radio altitude. Refer to the performance criteria in paragraph 4.5 of this AC.

2.4.5 Enhanced flight vision displays both symbology and imagery.

2.4.5.1 Symbology illuminates a small fraction of the total display area of the HUD, leaving much of that area free of reflected light that could interfere with the pilot's view out the window through the display.

2.4.5.2 The EVS image is in the center of the pilot's regulated "pilot compartment view." It should be free of interference, distortion, and glare that would adversely affect the pilot's normal performance and workload. A video image can be more difficult for the pilot to see through than symbols also displayed on the HUD. Unlike symbology, the video image illuminates, to some degree, most of the total display area of the HUD with much greater potential interference with the pilot compartment view. It is sufficient for the pilot to see around the video image, but the outside scene must be visible through and around it.

2.4.6 Unlike the pilot's external view, the enhanced flight vision image is a monochrome, two-dimensional display. Some, but not all, of the depth cues found in the natural view are also found in the imagery. The quality of the enhanced flight vision image and the level of enhanced flight vision sensor performance could depend significantly on the atmospheric and external light source conditions. Gain settings of the sensor, and brightness or contrast settings of the HUD, can significantly affect image quality. Certain system characteristics could create distracting and confusing display artifacts. Finally, this is a sensor-based system that is intended to provide a conformal perspective. Refer to Figure 1 for a diagram of the system.

2.4.7 Although the European Aviation Safety Agency (EASA) uses the term “EVS” as equivalent to the FAA “EFVS,” do not confuse an EFVS with an Enhanced Vision System (EVS).

2.4.7.1 Unlike with EFVS, an aircraft with EVS does not necessarily provide the additional flight information or symbology required by 14 CFR § 91.176. An EVS is not required to use a HUD, and may not be able to present the image and flight symbology in the same scale and alignment as the outside view. An EVS can provide situation awareness to the pilot, but does not meet the regulatory requirements of 14 CFR § 91.176. An EVS cannot be used as a means to determine enhanced flight visibility or to identify the required visual references in order to gain operational credit and descend below the DA/DH or MDA.

2.4.7.2 For the primary display, the regulations also make provision for an equivalent display. Specifically, 14 CFR § 91.176(a)(1)(i)(B) states that EFVS sensor imagery, aircraft flight information, and flight symbology must be presented “on a head up display, or an equivalent display, so that the imagery, information and symbology are clearly visible to the pilot flying in his or her normal position with the line of vision looking forward along the flight path.” An equivalent display must be some type of head-up presentation of the required information. A head-down display does not meet the regulatory requirement. For the monitoring display, see paragraph 4.5.2.1 of this AC.

CHAPTER 3. AIRWORTHINESS PACKAGE CONTENTS

3.1 Airworthiness Package

The applicant is responsible for the following contents in the airworthiness package (for the purpose of this AC). This AC specifically addresses SVS with attitude displayed on the primary flight display (PFD), EVS/SVS/CVS with a head down display other than a PFD (such as a navigation display or multifunction display), EVS image displayed on a head up display, and an EFVS.

3.1.1 Intended function: Information on intended function can be found in section 3.2.

3.1.2 General operation: Information on the general operations and specific performance criteria can be found in Chapter 4.

3.1.3 Performance criteria and evaluation plan for the respective system. Performance evaluation is addressed in Chapter 6 with sample test considerations found in the appendices of this document, and

3.1.4 Installation considerations: Information regarding installation considerations can be found in Chapter 5 of this document.

3.2 Intended Function.

3.2.1 EVS, SVS, or CVS: Define the intended functions of your EVS, SVS or CVS. Include what features you will display and the criticality of pilot decision-making using the display features. Define additional intended functions (for example, terrain alerting) according to AC 25-11B and 14 CFR §§ 23/25/27/29.1301.

3.2.2 EFVS: Clearly define the intended function of your EFVS (EFVS Approach System or EFVS Landing System). This must include its use to assess enhanced flight visibility and to visually acquire the visual references required to operate below the DA/DH or MDA as specified in 14 CFR §§ 91.176 (a) and (b), 121.651, 125.381, and 135.225, and the criticality of pilot decision-making based on what is visible using the EFVS display. The purpose of the EFVS is to provide a visual advantage over the pilot's out-the-window view using natural vision. In low visibility conditions, the "enhanced flight visibility" should exceed the "flight visibility" and the required visual references should become visible to the pilot at a longer distance with an EFVS than they would out-the-window using natural vision. Visual advantage using an EFVS must be demonstrated before descending below DA/DH or MDA because this is the point in an instrument approach procedure where the operating rules permit an EFVS to be used in lieu of natural vision for operational benefit.

Note 1: The EFVS is not intended to replace the technologies or procedures already used to safely fly the aircraft down to the MDA/MDH or DA/DH.

Note 2: While the goal of EFVS is to exceed the natural flight visibility in the majority of cases/weather conditions, there may be meteorological conditions where the EFVS does not provide a significant advantage.

Note 3: Past test data for existing EFVS sensor technology which demonstrated compliance should be considered for inclusion in this airworthiness package.

Note 4: Where appropriate, use of TSO criteria and performance can be beneficial to the FAA and the applicant.

CHAPTER 4. SYSTEM CRITERIA

4.1 EVS or SVS (or CVS when EVS and SVS combined) – General.

4.1.1 EVS/SVS/CVS Primary Displays. EVS, SVS, or CVS functionality can be superimposed on the electronic flight instrument system (EFIS), for example the primary flight display (PFD) as installed in the flight deck. In this configuration example, the EVS, SVS, or CVS image can be merged into the sky/ground shading of the attitude direction indicator. In addition to the traditional head down display PFD, this type of superimposed display could also be associated with a HUD or equivalent display system using EVS, SVS, or CVS capabilities. Maneuvering the aircraft during any phase of flight (taxi, approach, landing, rollout, etc.) shall not be predicated on EVS, SVS or CVS imagery alone.

4.1.2 EVS/SVS/CVS Secondary Displays. EVS, SVS, or CVS functionality can be selected on a multi-function display (MFD) or navigation display (ND) as one of many stand-alone type formats available in the flight deck. For example, an EVS, SVS, or CVS image can be one selection on the MFD, while an electrical synoptic could be another selection on the same MFD.

4.1.3 EVS, SVS, or CVS installed on side-mounted displays: While similar in concept to the MFD, side-mounted displays systems are, in general, limited due to the nature of the installation constraints of these devices. Side-mounted displays of EVS technologies can present unique certification challenges such as alignment or positioning concerns relating to the display installation. (See AC 120-76C, *Guidelines for Certification, Airworthiness, and Operational Use of Electronic Flight Bag*, for specific applications.)

4.1.4 The intended function for any installation of EVS/SVS/CVS must be clearly defined (appropriate 14 CFR §§ 23/25/27/29.1301), and the design and installation safety levels must be appropriate for the stated intended function. Although normally associated with use during flight, utilization of EVS display during ground operations should not be used if sensor proximity to the taxiway surface causes a distraction.

4.1.4.1 The intended function should be reasonable considering the actual functionality of the installation.

4.1.4.2 Operating limitations should be proposed to the FAA by the applicant. Operating limitations must be clearly defined and stated in the aircraft's flight manual supplement in line with the intended function.

4.1.4.3 An EVS must not be used for flight guidance or navigation. An EVS cannot be used in lieu of natural vision to descend below DA/DH or MDA under §§ 91.176, 121.651, 125.381, or 135.225 regardless of whether it is on a HUD, or on a head down display.

4.1.5 The proposed system (EVS, SVS, and/or CVS):

4.1.5.1 Should have a means to automatically or manually control display brightness.

4.1.5.2 Must not degrade presentation of essential flight information. In other words, the pilot's ability to see and use the required primary flight display information such as primary attitude, airspeed, altitude, and command bars/command guidance must not be hindered or compromised by the EVS/SVS/CVS image.

4.1.5.3 If the vision system uses a head-up display or the equivalent, then it may not distort the pilot compartment view, provide a distorted (i.e., non-conformal) view of the external scene, or interfere with the pilot's ability to safely perform any maneuvers within the operating limitations of the aircraft, including taxiing, takeoff, approach, and landing. See paragraph 4.1.6.2 of this chapter.

4.1.5.4 Must not adversely affect any other installed aircraft system.

4.1.5.5 Perform its intended function in each aircraft environment where system approval is desired. For example, if the system is intended to perform in (or after exposure to) known icing conditions, a means can be required to keep the EVS sensor window clear of ice accumulation.

4.1.5.6 Should display the mode of operation (EVS, SVS, or CVS) to the pilot/crew. Consideration should be given to recording the EVS/SVS/CVS display status in a flight data recorder or some form of nonvolatile memory.

4.1.5.7 Should not have undesirable display characteristics (for example, jitter, jerky motion, and excessive delays).

4.1.6 Display Implementation. EVS/SVS/CVS can be incorporated into differing display types installed in the cockpit. AC 25-11B, *Electronic Flight Displays* and AC 23.1311-1C, *Installation of Electronic Display in Part 23 Airplanes*, provide more information on electronic displays. The display is subject to all applicable primary flight information rules and guidance for the category of aircraft.

4.1.6.1 Primary Flight Display (PFD). Primary displays are cockpit displays used to provide information needed to guide and control the aircraft and provide the aircraft altitude, attitude, and airspeed indications. EVS/SVS/CVS can be implemented on the primary Head Down Display (HDD) in 14 CFR part 23 and 25 aircraft. Refer to AC 27-1B and AC 29-2C for guidance on installation on rotorcraft. The following criteria apply to EVS/SVS/CVS implemented on a PFD.

4.1.6.1.1 The image, or loss thereof, must not adversely affect the PFD functionality.

4.1.6.1.2 Align the displayed image with the aircraft's inertial axis, physical axis or as appropriate for the intended function. The alignment can be variable and/or "phase of flight" dependent. The relationship between the image and the aircraft's heading angle, pitch angle, roll angle, and track angle should generally align with the trajectory of the aircraft, should be recognizable by the flight crew, and not be misleading. For example, if two displays show EVS, SVS, or CVS information, or a combination (EVS on one and SVS on another), the orientation of the displays should be the same. Alignment of imagery presented on the PFD should be consistent with the real world and appropriate for the system's intended function accounting for possible aircraft attitudes, turbulence, and wind effects.

4.1.6.1.3 Scale and align all spatially referenced symbology within each axis with the imagery so as not to present any misleading information to the pilot.

4.1.6.1.4 The Field of Regard (FOR) can be variable, but must be designed to ensure the displayed image is not distracting or misleading and does not adversely affect crew performance and workload. (Reference 14 CFR §§ 23/25/27/29.771 and §§ 23/25/27/29.1309.)

4.1.6.1.5 The display should not impede a clearly visible zero pitch reference line, distinct in visual appearance relative to any possible terrain, obstacle, or cultural feature display appearance.

Note: Including a flight path vector or velocity vector to show the pilot the aircraft's trajectory relative to displayed terrain is recommended.

4.1.6.1.6 Per 14 CFR §§ 23/25/27/29.771 and §§ 23/25/27/29.773, pilot tasks must not be degraded by the displayed imagery. Depending on the intended function of the display information, the imagery must not provide the pilot with misleading information regarding detection, accurate identification, and avoidance of terrain, obstacles, and other flight hazards.

4.1.6.2 Head-Up Display or Equivalent. EVS/SVS/CVS can be implemented on a HUD, HDD or equivalent. The following criteria apply to EVS/SVS/CVS implemented on a HUD or equivalent display:

4.1.6.2.1 A design with EVS/SVS/CVS imagery displayed on a HUD must account for the pilot compartment view requirements found in 14 CFR §§ 23.773, 25.773, 27.773, and 29.773, including validation that the display of EVS imagery does not conflict with the pilot compartment view. The following tasks associated with the use of the pilot's view must not be degraded below the level of safety that existed without the EVS:

- Detection, accurate identification and maneuvering, as necessary, to avoid traffic, terrain, obstacles, and other hazards of flight.

- Accurate identification and utilization of visual references required for every task relevant to the phase of flight.

Note: Although normally associated with use during flight, utilization of video imagery on the HUD or equivalent display during ground operations should not be considered if sensor proximity to the taxiway surface causes a distraction.

4.1.6.2.2 Imagery on the HUD or equivalent display must be conformal with the real world and appropriate for the system's intended function accounting for possible aircraft attitudes, turbulence, and wind effects.

4.1.6.2.3 Society of Automotive Engineers (SAE) International design standards for HUD symbology, optical elements and video imagery are also prescribed with SAE Aerospace Standard (AS) 8055, *Minimum Performance Standard for Airborne Head Up Display (HUD)*, dated March 1999, SAE Aerospace Recommended Practice (ARP) 5288, *Transport Category Airplane Head Up Display (HUD) Systems*, dated May 2001, and SAE ARP 5287, *Optical Measurement Procedures for Airborne Head Up Display (HUD)*, dated March 1999. Apply specific design standards for resolution and line width, luminance and contrast ratio, chromaticity, and grayscale.

4.1.6.3 Secondary displays. EVS/SVS/CVS can be implemented with ego-centric "inside aircraft" views or exocentric "outside aircraft" viewpoints on head down displays. This includes installed EFBs or MFD. The following criteria apply to EVS/SVS/CVS implemented on secondary displays:

4.1.6.3.1 The orientation and perspective of the EVS/SVS/CVS view should be clear to the pilot.

4.1.6.3.2 If PFD information is displayed, it should meet PFD integrity requirements and availability criteria.

4.1.6.3.3 EVS/SVS/CVS image, or loss thereof, must not adversely affect other approved display functionality (such as navigation displays).

Note: Generally, the orientation of the secondary display should be the same as the primary display to decrease the possibility of pilot confusion.

4.2 EVS Specific Criteria.

4.2.1 An EVS requires a real-time imaging sensor and display, providing improved vision performance. These systems do not qualify for additional operational credit over and above what is already approved, and are installed on a non-interference basis.

4.2.2 EVS installations must meet the following criteria:

4.2.2.1 The EVS depiction must be crew de-selectable (if on the primary display, the pilot should be able to easily and quickly declutter the EVS or remove sensor image). For an EVS image displayed on a HUD or equivalent display, the system must provide a means to allow the pilot using the display to immediately deactivate and reactivate the vision system imagery, on demand, without removing the pilot's hands from the primary flight and power controls, or their equivalent.

4.2.2.2 The display mode (status of EVS), either through crew de-selection or as a result of a failure, should be clearly indicated or obvious to the crew.

4.2.2.3 The display and sensor FOR should be sufficient for the intended functions.

4.2.2.4 SAE design standards for EVS symbology, optical elements and video imagery are also prescribed in SAE AS 8055, SAE ARP 5288, and SAE ARP 5287. Apply the specific design standards for resolution and line width, luminance and contrast ratio, chromaticity, and grayscale.

4.2.2.5 Consider the following criteria for display characteristics for the EVS design, regardless of the display type:

4.2.2.5.1 For part 25 airplanes, apply all display characteristics listed in AC 25-11B. For part 23 airplanes, apply all display characteristics listed in AC 23.1311-1C. For other aircraft without corresponding criteria, the guidance in AC 25-11B or AC 23.1311-1C serves as recommended guidance.

4.2.2.5.2 The display should not have undesirable display characteristics (such as blooming, "burlap," and running water).

4.2.2.6 Image characteristics.

4.2.2.6.1 On a HDD, the relationship of the display FOR to the actual field of view should be suitable for the pilot to smoothly transition from the HDD to the out-the-window real world view or HUD or equivalent display. The recommended maximum display minification is 3:1.

4.2.2.6.2 The image data should be refreshed at 15 Hz or better.

4.2.2.6.3 The image latency should be less than 100 milliseconds where the latency is measured from the image source time of applicability to the display of the image.

Note: EVS display refresh rate, when used in direct aircraft or power plant manual control tasks (such as attitude, engine parameters, etc.), equal to, or greater than 15 Hz has been found to be acceptable. Any lag introduced by the display system should be consistent with the aircraft control task associated with that parameter. In particular, display system lag (including the sensor) for attitude which does not exceed a first order equivalent time constant of 100 milliseconds for aircraft with conventional control system response is generally acceptable.

4.2.2.7 For display on a HUD or equivalent display, the minimum system should provide a control of the EVS display contrast/brightness which is effective in dynamically changing background (ambient) lighting. In addition, the minimum system must not:

- distract the pilot,
- impair the pilot's ability to detect and identify visual references,
- mask flight hazards, or
- degrade task performance or safety.

4.2.2.8 When EVS is incorporated on the primary display, the EVS-based primary display must be clear and unambiguous when recovery from unusual attitudes is required. An accurate, easy, quick-glance interpretation of attitude should be possible for all unusual attitude situations and other "non-normal" maneuvers sufficient to permit the pilot to recognize the unusual attitude and initiate a recovery within one second. We recommend you use chevrons, pointers on all attitude indications to perform effective manual recovery from unusual attitudes. (For part 25 aircraft, refer to AC 25-11B. For part 23 aircraft, refer to Appendix H.)

4.3 SVS Specific Criteria.

4.3.1 Synthetic Vision Systems require a terrain and obstacle database, a precision navigation position, display, and height, attitude, and heading/track inputs. The design and installation safety levels should be appropriate for the system's intended function. AC 25-11B and AC 23.1311-1C provide additional general display guidance.

4.3.2 Image characteristics:

4.3.2.1 Failure or de-selection of the synthetic vision depiction should be obvious to the crew.

4.3.2.2 The display can depict the scene from the pilot's view looking through the front window (egocentric) or from outside the aircraft (exocentric). However, if implemented on a primary display, then the display should depict the scene from the pilot's perspective looking through the front window.

4.3.2.3 The Field of Regard (FOR) should be appropriate for the system's intended function and account for possible aircraft attitudes, turbulence, and wind effects (for example, to orient the line of sight according to heading and not to track). Synthetic vision scene compression can result from FOR selections or display size limitations. Regardless, prominent topographical features should be easily identified and must be correlated with the actual external scene.

4.3.2.4 Identify dominant topographical features present in the SVS image in the outside view. Dominant topographical features present in the outside view should also be identifiable in the SVS image.

4.3.2.5 Terrain:

4.3.2.5.1 A potential terrain or obstacle conflict should be obvious to the pilot, and must not conflict with TAWS or HTAWS requirements. One mechanism for making such conflicts obvious on a primary display is an earth-based flight path vector. For guidance regarding alerts, use AC 23.1311-1C or AC 25.1322-1.

4.3.2.5.2 Displayed topographical features should not intersect guidance provided to the pilot to fly a published approach path. Terrain and 3-space position resolution should be accurate enough that topographical features should not intersect published approach paths.

4.3.2.5.3 Threatening terrain, close enough to generate a terrain warning alert, should appear above the artificial horizon zero pitch reference line if it is higher than the aircraft altitude.

4.3.2.6 SVS-based primary displays must be clear and unambiguous when recovery from unusual attitudes is required. An accurate, easy, quick-glance interpretation of attitude should be possible for all unusual attitude situations and other “non-normal” maneuvers sufficient to permit the pilot to recognize the unusual attitude and initiate a recovery within one second. We recommend you use chevrons, pointers, and/or permanent ground-sky horizon on all attitude indications to perform effective manual recovery from unusual attitudes. (For part 25 aircraft, refer to AC 25-11B. For part 23 aircraft, refer to Appendix H.) Always have some indication of both sky and ground visible on the PFD for use in initiating unusual attitude recovery. SVS displays used as an attitude indicator require an egocentric orientation.

4.3.2.7 The relationship of the display FOR to the actual field of view should be suitable for the pilot to smoothly transition from the head-down display to the head-up, out-the-window real features.

4.3.2.8 The terrain depiction should include large bodies of water. Differentiation between water and sky depictions should be clearly distinguishable.

4.3.2.9 The pilot’s view should not be depicted below the earth’s surface.

4.3.2.10 The image should be updated at 15 Hz or better and function smoothly during all expected maneuvering reasonable for the class and type of aircraft.

4.3.2.11 The image latency for a PFD or HUD or equivalent display should be consistent with the image guidance in AC 25-11B or that necessary for expected maneuvering reasonable for the class and type of aircraft. For other displays in the flight deck, a larger lag can be acceptable subject to the intended function.

4.3.2.12 Undesirable display characteristics should be minimized (for example, jitter, jerky motion, and excessive delays).

4.3.2.13 Range:

4.3.2.13.1 The scene range should be the natural horizon for both egocentric and exocentric displays. For systems intended for use in approach, missed approach, take-off, and departure operations, the scene range should be whichever is less of the following: natural horizon, 40 nautical miles, or 10 minutes at maximum cruise speed.

4.3.2.13.2 The scene range from the eye position to the terrain horizon must not be misleading and must be appropriate to the intended function. The intent is to prevent misleading information due to a SVS range limitation to the horizon that could lead to crew confusion at a critical phase of flight. At some airports the missed approach can take the aircraft on a course towards mountains. Pilots need to see that the mountains will be a factor in their missed approach long before they get to the runway. Thus, it is not acceptable for an approach to appear as if it is over flat terrain until short final when the mountains in the distance finally start appearing on the PFD.

4.3.2.14 Although every possible scenario cannot be described, the crew should be able to perceive relative distances to prominent topographical features. For example, the pilot should be able to identify an immediate terrain threat versus a distant terrain conflict.

4.3.2.15 All obstacles taller than 200 feet above ground level should be displayed. These obstacles must be displayed in the scaled and aligned position relative to other features on the synthetic vision image.

Note: Obstacle display consideration should be given to reducing clutter when objects pose no threat, yet not suddenly appear at low altitudes during periods of task saturation.

4.3.3 Position Source. The horizontal position source used for the SVS display should at least meet the criteria for TAWS or HTAWS. The horizontal position source must not provide contradictory indications of horizontal terrain clearance. Additional guidance for the horizontal position source can be necessary, depending on the intended functions of the SVS. TAWS guidance is contained in AC 25-23 and AC 23-18. HTAWS guidance is contained in AC 27-1B and 29-2C.

4.3.3.1 The synthetic vision display must not conflict with either the terrain warning or terrain awareness functions (for example, TAWS or HTAWS).

4.3.3.2 Any aircraft incorporating SVS from the egocentric perspective should also provide a TAWS or HTAWS or terrain warning system (refer to Appendix H for specifics on a terrain warning system). If terrain alerts and cautions are depicted on the SVS, they must be consistent across all displays in the cockpit when terrain threats are identified. In other words, terrain database sources should be consistent.

4.3.4 Altitude Source. The altitude source used for the SVS display should meet the criteria for TAWS or HTAWS installations, including the need to account for cold temperature errors which could place the aircraft closer to the surface than the altimeter indicates. The altitude source should be consistent with that used for the onboard terrain awareness and alerting system on the aircraft and must not provide contradictory indications of vertical terrain clearance. Additional criteria for the altitude source may be necessary, depending on the intended functions of the SVS. TAWS guidance is contained in AC 25-23 and AC 23-18. HTAWS guidance is contained in AC 27-1B, AC 29-2C, and TSO-C194.

4.3.5 Attitude Source. The attitude source must not conflict with attitude information or integrity criteria provided by the primary flight display.

4.3.6 Heading/Track Source. The heading/track source must not conflict with heading/track information provided by the navigation display.

4.3.7 Terrain and Obstacle Database.

4.3.7.1 Terrain and obstacle database processing. The terrain and obstacle database, along with any other database used to create the SVS image should be compliant to RTCA/DO-200A, as applicable to the intended function. The minimum terrain database resolution and accuracy must be consistent with the intended function, and should comply with the resolution and accuracy listed in TSO-C151, Appendix A, section 6.3, or for helicopters, TSO-C194.

- Position accuracy, symbology, and topographical information should be consistent with each other.
- Runway elevations must be accurate at the approach ends and not just at the airport center.

4.3.7.2 Obstacle database. The obstacle database should include all available physical hazards greater than 200 feet above ground level, not just terrain. The system should neither disregard nor corrupt obstacles available in the database greater than 200 feet above ground level. Obstacles displayed should be those deemed hazardous to the flight (or phase of flight). The applicant should provide procedures in the Instructions for Continued Airworthiness to ensure the most current obstacle database is installed.

Note: It is difficult to apply one altitude value across a wide range of aircraft performance, from rotary wing to high performance fixed wing. Generally, above 5,000 ft AGL, most obstacles are not tall enough to be hazardous. However, in the airport terminal area, even obstacles less than 1,000 ft AGL can be hazardous.

4.3.7.3 Navigation Database. The navigation database used by SVS for runway and airport information should be consistent with that used by other systems in the aircraft (for example, flight management systems). The applicant should provide procedures to document database currency in the Instructions for Continued Airworthiness.

4.3.7.4 Features. If flight path guidance features are provided by the SVS, they should complement (or correspond with) approved navigation system guidance.

4.3.7.5 Head-Up Displays. Providing complete guidance for synthetic vision systems is complicated by the many design variables available to manufacturers. Since synthetic vision displays can share many characteristics with a HUD, applicants should use HUD display guidance where appropriate.

4.3.7.6 Terrain display. If the intended function is “terrain awareness,” then “awareness” is consistent with the actual terrain. The display may not match the terrain perfectly, but the display should provide a reasonable representation of the terrain in a manner that does not misrepresent the threat posed by the terrain. The display, while possibly resolution or field-of-view limited, may still adequately portray terrain awareness. The pilot should be aware of less than a 1:1 ratio of depiction. The pilot could be made aware of this ratio by training, the Airplane Flight Manual, symbology or other means. Display suitability must be matched against intended function.

4.4 CVS Specific Criteria.

4.4.1 CVS requires a real-time imaging sensor and display that provides demonstrated vision performance for its intended function. They also require a terrain and obstacle database and a precision navigation position for the synthetic portion of the display. The design assurance levels should be appropriate for the system’s intended function. The following criteria apply to CVS installations:

4.4.1.1 CVS should meet the respective criteria of the EVS and SVS implementations.

4.4.1.2 The EVS and SVS depictions should be conformal with each other.

4.4.1.3 Fusion of EVS and SVS should require the images to be aligned within 5 milliradian (mrad) laterally and vertically at the boresight of the display. Therefore, blended EVS and SVS images should not cause confusion to the flight crew. Significant image discrepancies between EVS and SVS due to failure conditions should be obvious to the crew.

Note: It is difficult to define every implementation in order to determine what is “significant.” However, the applicant is expected to reduce discrepancies to as near-zero as possible. The final determination will occur during flight test.

4.4.2 The CVS should meet the detailed performance criteria for EVS and SVS specified in paragraphs 4-2 and 4-3 of this chapter.

4.5 EFVS – General and Specific Criteria.

4.5.1 EFVS criteria would meet EVS criteria. However, there are additional EFVS general and specific criteria for operational credit, as follows:

4.5.1.1 Mitigate system failures more frequent than extremely improbable which produce effects the pilot (or the aircraft itself) cannot safely handle. Design the aircraft systems so the entire fault probability is kept to an acceptable level, and complies with 14 CFR part §§ 23/25/27/29.1309 regulations.

4.5.1.2 The sensor image, combined with the required aircraft state and position reference symbology, is presented to the flight crew on the HUD, or an equivalent display, so 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. For HUD or equivalent display operations, the pilot flying views the EFVS sensor and symbolic information that is properly aligned and registered to enable a one-to-one (conformal) overlay with the actual external scene.

4.5.1.3 The HUD or equivalent display and displayed FOR should be sufficient for the EFVS information to be displayed conformally over the range of anticipated aircraft attitudes, aircraft configurations, and environmental (for example, wind) conditions. The aircraft state and position reference data is presented in the form of symbology overlaying the image presentation. The flight instrument data on the HUD or equivalent display must include:

- Airspeed;

- Vertical speed;
- Aircraft attitude;
- Heading;
- Altitude;
- Command guidance as appropriate for the approach to be flown;
- Path deviation indications;
- Flight path vector; and
- Flight path angle reference cue.

4.5.1.4 For an EFVS Landing System intended for landing (i.e., from DA/DH through touchdown and roll out at not less than1000ft RVR, the following specified aircraft flight information, in addition to that noted above in 4.5.1.3, must also be displayed:

- Height above ground level such as that provided by a radio altimeter or other device capable of providing equivalent performance, and
- Flare prompt or flare guidance for achieving acceptable touchdown performance, as discussed in paragraph 6.2.

4.5.1.5 The minimum system should include a control of EFVS display contrast/brightness which is effective in dynamically changing background (ambient) lighting, prevents distractions to the pilot, prevents impairment of the pilot's ability to detect and identify visual references, prevents masking of flight hazards, or otherwise degrades task performance or safety. If automatic control for image brightness is not provided, it should be shown that manual setting of image brightness meets the above criteria and does not cause excessive workload.

4.5.1.6 The EFVS display controls should be visible to, and within reach of, the pilot flying from any normal seated position. If each pilot station is equipped with EFVS, the EFVS display controls should be visible to, and within reach of, the respective pilot from any normal seated position. The position and movement of the controls should not lead to inadvertent operation. The EFVS controls, except those located on the pilot's control wheel, should be adequately illuminated for all normal background lighting conditions, and should not create any objectionable reflections on the HUD or equivalent display or other flight instruments. There must be a means to allow the pilot using the display to immediately deactivate and reactivate the vision system imagery, on demand, without removing the pilot's hands from the primary flight and power controls, or their equivalent. (Ref 14 CFR §§ 23.773(c)(3), 25.775(e)(3), 27.773(c)(3), and 29.773(c)(3)).

4.5.1.7 The approach path situation references and command guidance should be based on the navaid for the straight-in instrument approach procedure in use.

4.5.1.8 Under 14 CFR § 91.176, upon reaching the decision altitude/decision height (DA/DH) or minimum descent altitude/minimum descent height (MDA/MDH), the required visual references presented in Table 1 must be distinctly visible and identifiable to the pilot. Sensor performance criteria can be quantified in terms of the range of the enhanced flight visibility compared to the flight visibility when low visibility conditions exist. The visual references of the runway environment must be seen by the sensor at operationally relevant distances.

Table 1. EFVS Visibility and Visual Reference Requirements

From the authorized DA/DH to 100 feet height above touchdown zone elevation of the runway of intended landing, the approach light system (if installed) or both the runway threshold and the touchdown zone are distinctly visible and identifiable to the pilot using an EFVS. (A) The pilot must identify the runway threshold using at least one of the following visual references - (1) The beginning of the runway landing surface; (2) The threshold lights; or (3) The runway end identifier lights. (B) The pilot must identify the touchdown zone using at least one of the following visual references - (1) The runway touchdown zone landing surface; (2) The touchdown zone lights; (3) The touchdown zone markings; or (4) The runway lights At 100 feet height above touchdown zone elevation of the runway of intended landing and below that altitude, the enhanced flight visibility using EFVS is sufficient for one of the following visual references to be distinctly visible and identifiable to the pilot. For EFVS Approach System operations the listed features must be identified without reliance on the EFVS Approach System. For EFVS Landing and Rollout Operations the listed features may be identified using an EFVS Landing System. (A) The runway threshold; (B) The lights or markings of the threshold (C) The runway touchdown zone landing surface; or (D) The lights or markings of the touchdown zone.

4.5.1.9 The minimum detection EFVS range (figure 3, below) can be derived by using an assumed minimum distance of the aircraft at the nominal

Category I (200 ft) decision altitude before which the EFVS should image the runway threshold. On a 3 degree glide slope, the horizontal distance from the aircraft to the runway threshold is approximately 2816 feet (3816 feet from the precision touchdown zone markers). Use this range as a minimum performance value. These values do not take into account pilot decision time or actual atmospheric conditions, the use of non-precision approaches which can require greater distances, or the use of approaches with higher DAs, DHs, or MDAs.

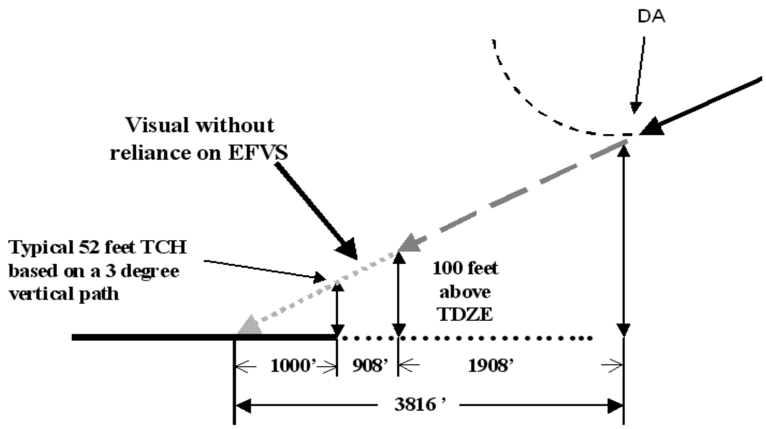

Figure 3. Minimum Detection Range

4.5.1.10 The EFVS imagery displayed on the HUD or equivalent display must account for the pilot compartment view requirements found in 14 CFR §§ 25.773, 23.773, 27.773, and 29.773, including validation that the display of imagery does not conflict with the pilot compartment view. The display of EFVS sensor imagery must be on a system that compensates for the interference caused by the provided imagery. Additionally, the system must provide an undistorted and conformal view of the external scene, a means to deactivate the display and does not restrict the pilot from performing specific maneuvers. The following tasks associated with the use of the pilot's view must not be degraded below the level of safety that existed without the video imagery:

- Detection, accurate identification and maneuvering, as necessary, to avoid traffic, terrain, obstacles, and other hazards of flight.
- Accurate identification and utilization of visual references required for every task relevant to the phase of flight.

Note: Although, the EFVS image requirements relate primarily to the approach and landing phases of flight, the EFVS image when viewed head up during ground operations should not create unacceptable distractions due to sensor proximity to the taxiway surface.

4.5.2 EFVS General System Criteria.

4.5.2.1 For EFVS implemented on a HUD, the image must be compatible with the FOV and head motion box of a HUD designed against SAE ARP 5288 (transport category head-up display (HUD) systems). When used in a given phase of flight, the HUD and EFVS FOR must provide a conformal image with the visual scene over the range of aircraft attitudes and wind conditions. A display that provides the pilot monitoring with EFVS sensor imagery is not required for EFVS Approach System operations. However, for EFVS Landing System operations, when a minimum flightcrew of more than one pilot is required for the conduct of the operation, the aircraft must be equipped with an operable display that provides the pilot monitoring with EFVS sensor imagery. Any display used to monitor the approach must be located in the cockpit in accordance with 14 CFR §§ 23/25/27/29.1321 so that any pilot seated at the controls can monitor the airplane's flight path and instruments with minimum head and eye movement. Aircraft that pre-date 14 CFR §§ 23/25/27/29.1321 must meet the arrangement and visibility requirements in those sections for the installation of pilot monitoring displays. Any symbology displayed must not adversely obscure the sensor imagery of the runway environment.

4.5.2.2 EFVS display criteria must meet the airworthiness certification requirements in 14 CFR parts 21, 23, 25, 27, and 29 (as applicable), see Appendix A. Some of these requirements could be specific to EFVS and could be in addition to all other requirements applicable to the HUD and the basic avionics installation.

4.5.2.3 The current FAA guidelines for head-up displays apply with respect to EFVS. These criteria include well-established military as well as civil aviation standards for HUDs as defined in MIL-STD-1787C, *Aircraft Display Symbology*, and AC 25-11B. SAE design standards for HUD symbology, optical elements, and video imagery are also prescribed within SAE AS 8055, SAE ARP 5288 and SAE ARP 5287. Apply specific design standards for image size, resolution and line width, luminance and contrast ratio, chromaticity, and grayscale.

4.5.2.4 The EFVS image, when superimposed on the HUD symbology and when used in combination with other aircraft systems, must meet the criteria below. The EFVS image and installation must:

4.5.2.4.1 Be suitable for and successfully perform its intended function.

4.5.2.4.2 Allow the accurate identification and utilization of visual references, using both EFVS and natural vision as appropriate.

4.5.2.4.3 Have acceptable display characteristics to accomplish the intended function.

4.5.2.4.4 There must be a means to allow the pilot using the display to immediately deactivate and reactivate the vision system imagery, on demand, without removing the pilot's hands from the primary flight and power controls, or their equivalent. (Ref 14 CFR §§ 23.773(c)(3), 25.775(e)(3), 27.773(c)(3), and 29.773(c)(3)).

4.5.2.4.5 Not degrade the presentation of essential flight information on the HUD or equivalent display.

4.5.2.4.6 Not be misleading and should not cause confusion or any significant increase in pilot workload.

4.5.2.4.7 Be aligned with and scaled to the external scene, and should include the effect of near distance parallax.

4.5.2.4.8 Not cause unacceptable interference with the safe and effective use of the pilot compartment view.

4.5.2.4.9 Not misleadingly alter the color perception of the external scene so as to preclude the pilot's performance of any required tasks by causing confusion or any significant increase in its workload, e.g. discerning PAPI lights accurately on approach.

4.5.2.4.10 Allow the pilot to recognize significantly misaligned or non-conformal conditions to the external scene that may preclude the pilot's performance of any required maneuvers.

4.5.2.5 Additionally, the EFVS installation and image should have an effective control of EFVS display brightness without causing excessive pilot workload and not cause adverse physiological effects such as fatigue or eyestrain.

4.5.2.6 A HUD modified to display EFVS must continue to meet the conditions of the original approval and be adequate for the intended function, in all phases of flight in which the EFVS is used. An accurate, easy, quick-glance interpretation of attitude should be possible for all unusual attitude situations and other "non-normal" maneuvers to permit the pilot to recognize the unusual attitude and initiate recovery within one second. We recommend you use chevrons, pointers, and/or permanent ground-sky horizon on all attitude indications to perform effective manual recovery from unusual attitudes. Refer to AC 25-11B for guidance on electronic flight deck displays.

4.5.2.7 14 CFR § 91.176 requires that the EFVS display a flight path vector (FPV) and flight path angle reference cue (FPARC) on the HUD or equivalent display. The following criteria apply to these symbols:

4.5.2.7.1 The position and motion of the FPV should correspond to the aircraft's earth referenced flight path vector.

4.5.2.7.2 The dynamic response of FPV should follow pilot control inputs. Refer to SAE ARP 5589 for dynamic response guidance.

4.5.2.7.3 The display of the FPARC should be suitable for monitoring the vertical flight path of the aircraft.

4.5.2.7.4 The system must provide the pilot a means to select the desired descent angle that is represented by the FPARC, and may also provide a means for the descent angle to be selected automatically from a database.

4.5.2.8 The display of attitude symbology, FPV, FPARC, and other visual elements which are earth-referenced, must be aligned with and scaled (i.e., conformal) to the external view.

4.5.2.9 The EFVS display of imagery, flight information and flight symbology should be a suitable visual reference for the pilot during the manual performance of any maneuvers within the operating limitations of the aircraft, including taxiing, takeoff, approach, landing and rollout.

4.5.3 EFVS Detailed System Criteria.

4.5.3.1 The performance of EFVS imaging systems does not solely depend upon system design, but also depends upon the target scene characteristics such as the runway, light structures, electromagnetic radiation, and atmospheric conditions.

4.5.3.2 Since the purpose of the EFVS sensor is to provide a visual advantage over the pilot's out-the-window view, the design should include a general performance analysis. This analysis includes calculated performance, which indicates the viability of the system to meet the proposed intended function, specifically including the calculated performance of the sensor operation within the range of the environment proposed.

4.5.3.3 Likewise, since the purpose of the EFVS sensor is to provide a visual advantage over the pilot's out-the-window view, the general performance analysis should include the calculated transmission of electromagnetic energy in the visible spectrum and other relevant frequencies. The analysis should portray length of transmission over a path with generalized extinction coefficients at a given wavelength.

Note: Examples of acceptable sensor models are MODTRAN and LOWTRAN which can be used to estimate the performance of infrared systems. Other models (FASCODE) for radar systems may be used for these types of sensors and provide a basic measure of signal attenuation helpful in assessing performance and viability for the functions required under 14 CFR § 91.176.

4.5.3.4 Minimum system performance. Integration of the major components includes the installed sensor, its interconnections with the sensor display processor, the display device, pilot interface, and aircraft mechanical interface, which can include the radome for the sensor.

4.5.3.4.1 Latency. EFVS latency should be no greater than 100 milliseconds (msec). A longer lag time can be found satisfactory, provided it is demonstrated not to be misleading or confusing to the pilot. Latency should not be discernible to the pilot and should not affect control performance or increase pilot workload. EFVS latency causes, at best, undesirable oscillatory image motion in response to pilot control inputs or turbulence. At worst, EFVS latency may cause pilot-induced oscillations if the pilot attempts to use the EFVS for active control during precision tracking tasks or maneuvers in the absence of other visual cues.

4.5.3.4.2 EFVS FOR. The minimum fixed FOR should be 20 degrees horizontal and 15 degrees vertical. In applications where the FOR is centered on the flight path vector the minimum vertical FOR should be 5 degrees (± 2.5 degrees) and 20 degrees horizontal.

4.5.3.4.2.1 The minimum EFVS FOR should not only consider the HUD FOV (i.e., how large of an area displayed), but also the area over which this area subtends (i.e., what is shown on the conformal display). The FOR portrayed on the HUD is established by three primary determinants:

- HUD and EFVS sensor Field-Of-View;
- Orientation of the HUD with respect to the aircraft frame of reference (for example, boresight and proximity to pilot's eye); and
- Orientation (for example, attitude) of the aircraft.

4.5.3.4.2.2 SAE ARP 5288 states, "The design of the HUD installation should provide adequate display fields-of-view in order for the HUD to function correctly in all anticipated flight attitudes, aircraft configurations, or environmental conditions such as crosswinds for which it is approved. Limitations should be clearly specified in the AFM if the HUD cannot be used throughout the full aircraft flight envelope." A quantitative EFVS FOR was established as minimum design criteria to be qualitatively checked during certification flight test for sufficiency in meeting its intended function. The EFVS FOR requirement resulted after consideration of the minimum field of regard criteria for various aircraft attitudes and wind conditions using a critical altitude of 200 ft height above touchdown zone elevation for EFVS visibility.

4.5.3.4.2.3 A variable FOR is permissible assuming a slewable sensor (i.e., variable field-of-regard), centered on the Flight Path Vector, with a minimum +/- 2.5 deg about the flight path vector to allow for momentary flight path perturbations and to allow sufficient fore/aft view of the required visual references.

4.5.3.4.3 Off-axis rejection. A source in object space greater than 1 degree outside the FOV should not result in any perceptible point or edge like image within the field of view. The EFVS should preclude off-axis information from folding into the primary FOR imagery, creating the potential for misleading or distracting imagery.

4.5.3.4.4 Jitter. When viewed from the HUD eye reference point, the displayed EFVS image jitter amplitude should be less than 0.6 mrad. Jitter for this use is defined in SAE ARP 5288. This implies the EFVS and HUD cannot exhibit jitter greater than that of the HUD itself.

4.5.3.4.5 Flicker. Flicker is brightness variations at frequency above 0.25 Hz per SAE ARP 5288. The minimum standard for flicker should meet the criteria of SAE ARP 5288. Flicker can cause mild fatigue and reduced crew efficiency. The EFVS and HUD cannot exhibit flicker greater than that of the HUD itself.

4.5.3.4.6 Image artifacts. The EFVS must not exhibit any objectionable noise, local disturbances, or an artifact that hazardously detracts from the use of the system. The EFVS design should minimize display characteristics or artifacts (for example, internal system noise, “burlap” overlay, or running water droplets) which obscure the desired image of the scene, impair the pilot's ability to detect and identify visual references, mask flight hazards, distract the pilot, or otherwise degrade task performance or safety.

4.5.3.4.7 Image conformality. The accuracy of the integrated EFVS and HUD image should not result in a greater than 5 mrad display error at the center of the display at a range of 2000 ft (100 ft altitude on a 3 degree glideslope). In accordance with SAE ARP 5288, the total HUD system display accuracy error as measured from the HUD eye reference point, should be less than 5.0 mrad at the HUD boresight, with increasing error allowable toward the outer edges of the HUD. Errors away from the boresight should be as defined in SAE ARP 5288. The primary EFVS error components include the installation misalignment of the EFVS sensor from aircraft/HUD boresight and sensor parallax. A range parameter is used in the EFVS conformability requirement to account for the error component associated with parallax. There is no error allowed for the EFVS sensor, since it is assumed any error can be electronically compensated during installation. With EFVS operations, the aircraft is flown essentially irrespective of the EFVS/HUD dynamic error, to the MDA or DA. From this point to 100 ft height above touchdown zone elevation, the EFVS conformality error introduces error in the pilot's ability to track along the extended centerline/vertical glide path as the pilot flies the flight path vector and glidepath reference line toward the EFVS image of the runway.

4.5.3.4.8 Sensor/sensor processor.

4.5.3.4.8.1 Dynamic range. The minimum required dynamic range for passive EFVS should be 48 db. For active EFVS, side lobes should be 23 db below the main beam, and 40 db dynamic range plus sensitivity time control (STC).

4.5.3.4.8.2 Sensor image calibration. Visible image calibrations and other built-in tests that cannot be achieved within a total latency of 100 milliseconds should occur only on either pilot command or be coordinated by aircraft data to only occur in non-critical phases of flight. If other than normal imagery is displayed during the non-uniformity correction (NUC) or other built-in tests, the image must be removed from the pilot's display. This prohibits excessive times to complete maintenance or calibration functions which would remove or degrade the EFVS imagery during critical phases of flight, unless the pilot commands the action (with full knowledge of effect based on training and experience). Abnormal imagery should be removed from the display to eliminate the potential for any misleading information.

4.5.3.4.8.3 Sensor resolution. As a minimum, EFVS resolution performance shall adequately resolve (for pilot identification) the runway threshold and the touchdown zone to enable the intended function. For example, an EFVS should resolve a 60 ft wide runway from 200 ft height above touchdown zone elevation with a typical 3-degree glide slope. The sensor resolution was established by providing this resolution at a minimum range, allowing the pilot to continue the descent below DA or MDA. (These values do not take into account pilot decision time or actual atmospheric conditions, or the use of non-precision approaches which may require greater distances.) A 60 ft wide runway was chosen as the ICAO minimum runway width to support an instrument approach procedure.

4.5.3.4.8.4 Passive sensor optical distortion. Optical distortion should be 5 percent or less across the minimal FOR as defined in paragraph 4.5.3.4.2 and no greater than 8 percent outside the minimal FOR.

4.5.3.4.8.5 Sensor sensitivity. In this context, the EFVS sensor sensitivity should be at least a noise equivalent temperature difference (NETD) of 50^{o} mK tested at an appropriate ambient temperature, for passive EFVS systems or -20dB sm/sm (square meter/square meter) surface at R_{max} from 200 ft height above touchdown zone elevation with a typical 3-degree glide slope for active EFVS systems. Passive sensors for different visible or short-wave infrared sources can require very sensitive detectors, as specified by low noise equivalent powers.

4.5.3.4.8.6 Failure messages. EFVS malfunctions detected by the system, and which can adversely affect the normal operation of the EFVS, should be annunciated. As a minimum, specific in-flight failure message(s) for sensor failure and frozen image must be displayed to the flight crew.

4.5.3.4.8.7 Blooming. The sensor should incorporate features to minimize blooming, which can create an unusable or objectionable image. Objectionable blooming is defined as the condition that obscures the required visual cues defined in Figure 3. Blooming to the extent the required visual references are no longer distinctly visible and identifiable is unacceptable.

4.5.3.4.8.8 Image persistence. The image persistence time constant should be less than 100 milliseconds. However, burn-in or longer image persistence caused by high energy sources (for example, the sun saturating the infrared sensor elements), should be removed from the image to comply with paragraph 4.5.3.4.6, Image artifacts, by a secondary on-demand process (for example, the NUC process).

4.5.3.4.8.9 Dead pixels. Dead pixels or sensor elements replaced by a "bad pixel" replacement algorithm should be limited to 1 percent average of the total display area, with no cluster greater than 0.02 percent within the minimum FOR. A small number of disparate dead pixel elements can be effectively replaced by image processing but eventually, the algorithms will degrade the image quality and accuracy due to the sheer number and closely-spaced location of the element.

4.5.3.4.8.10 Parallax. The effects of parallax caused by lateral, vertical, and longitudinal offset of the sensor from the pilots' design eye points may not impede the EFVS from performing its intended function, as evaluated during flight test. Parallax should not cause unsatisfactory landing performance parameters (e.g., flare height; sink rate, touchdown location; groundspeed during landing, exit and taxi) between EFVS operations and visual operations in the same aircraft.

CHAPTER 5. SYSTEMS INSTALLATION CONSIDERATIONS

5.1 EVS/SVS/CVS Installations Considerations

5.1.1 EVS/SVS/CVS Pilot Controls.

5.1.1.1 The EVS/SVS/CVS display controls should be visible to, and within reach of, the pilot flying from any normal seated position. The position and movement of the controls should not lead to inadvertent operation.

5.1.1.2 The EVS/SVS/CVS controls, except those located on the pilot's control inceptor (e.g., control wheel, yoke, stick, etc.), must be adequately illuminated for all normal background lighting conditions and must not create any objectionable reflections on other flight instruments.

5.1.1.3 There must be a means to modulate illumination unless fixed illumination of the EVS/SVS/CVS controls is shown to be satisfactory under all lighting conditions.

5.1.2 EVS/SVS/CVS Preventive Maintenance. Use manufacturer data for preventive maintenance (for example, Instructions for Continued Airworthiness, per 14 CFR § 21.50 and FAA Order 8110.54A), or other methods, techniques, and practices acceptable to the Administrator.

5.1.3 EVS/SVS/CVS Built-In Test (BIT). Provide a BIT capability that, at a minimum, limits the exposure time to latent failures consistent with the exposure limits in the system safety assessment.

5.1.4 The electrical system must be able to furnish the required power at the proper voltage for the EVS/SVS/CVS.

5.1.5 EVS/SVS/CVS System Safety Design Criteria. The overall safety requirement of the aircraft is based on installed equipment. A complete functional hazard assessment (FHA) and system safety analysis (SSA) should be conducted to identify failure modes and classify the hazard levels. To meet the safety criteria in 14 CFR §§ 23/25/27/29.1309, the system design will be demonstrated through analysis and engineering tests to preclude failures that can cause hazardously misleading information to be presented to the pilot or crew, or which can otherwise subsequently cause an unsafe condition. The following guidelines do not preclude the results of a full SSA. The results of an SSA found acceptable to the FAA should prevail.

5.1.6 EVS/SVS/CVS Required Safety Level.

5.1.6.1.1 The airworthiness standard under which approval is sought can impact criticality (for example, 14 CFR part 23, 25, 27, or 29). Recognizing that each implementation and integration of each installation can be unique, the applicant should perform a thorough FHA, SSA, and Failure Mode and

Effects Analysis (FMEA). A system safety assessment should be performed in accordance with 14 CFR §§ 23/25/27/29.1309 that addresses both the loss as well as the incorrect display of information, including hazardously misleading information. Undetected failure conditions which cause a hazardously misleading EFVS depiction must have a probability no greater than that appropriate for the hazard effects they create.

5.1.6.1.2 To support the 14 CFR §§ 23/25/27/29.1309 analysis (as applicable), the applicant must perform a safety assessment based on the proposed installation for the given aircraft and intended function for each phase of flight. Information presented to a pilot on a PFD is considered truth unless flagged otherwise. Therefore, presenting hazardously misleading information to the pilot must be avoided. One example of hazardously misleading information (HMI) would be the aircraft level ramifications of a "frozen EVS/SVS/CVS display" that is undetected by the flight crew.

5.1.6.1.3 Once the safety assessment has been completed, for any hazard or failure classification greater than Major, a fault tree analysis (FTA) should be evaluated using the guidance found in the FAA system safety advisory circular that is applicable to the installation (e.g., AC 23.1309-1E, AC 25.1309-1A, AC 27-1B (containing AC 27.1309) and 29-2C). The FTA should include the display monitor, power supply, IR camera and sensors, cable, status annunciations, and other components that affect the top-level events.

5.1.6.1.4 The variables influencing the outcome of the failure condition and its classification vary between 14 CFR parts 23, 25, 27, and 29. In general, the sensor or system performance and level of design should be consistent with the SSA. Table 2 provides sample system operating phases for consideration. The results of an SSA found acceptable to the FAA should prevail.

Table 2. System Operating Phases for Considerations

GROUND	TAKEOFF	IN-FLIGHT	LANDING
(1)Taxi (2) Maintenance	(1) Takeoff Roll Prior to V_1, (2) Takeoff Roll After V_1, (3) Takeoff After V_R to 200' (4) Rejected Takeoff	(1) Climb (2) Gear Up, (3) Cruise (4) Descent, (5) Gear Down, (6) Approach 200' to 0' (7) Go Around	(1) Touchdown & Rollout (2) Taxi

5.1.6.1.5 The normal operation (without malfunction) of the EVS/SVS/CVS may not adversely affect, or be adversely affected by other normally operating aircraft functions. The criticality of the EVS/SVS/CVS system's function to display imagery, including the potential to display hazardously misleading information, should be assessed according to the applicable 14 CFR §§ 23/25/27/29.1309, AC 25-11B chapter 4, and AC 23/25/27/29.1309, System Safety Analysis and Assessment for Part 23/25 Airplanes. Likewise, the hazard effects of any malfunction of the EVS/SVS/CVS that could adversely affect interfaced equipment or associated systems should be determined and assessed according to the applicable 14 CFR §§ 23/25/27/29.1309, AC 25-11B chapter 4, and AC 23/25/27/29.1309. As applicable, similar criteria are found in SAE ARP 4754, and ARP 4761.

5.1.7 EVS/SVS/CVS Environmental Specifications. The EVS/SVS/CVS should meet all specified operating conditions and should provide required operating performance, life and reliability when operating within the aircraft and subsystem flight envelope as specified in RTCA DO-160F (or as revised) Environmental Conditions and Test Procedures for Airborne Equipment. These criteria must also include the high-intensity radiated fields (HIRF), electromagnetic interference (EMI), and lightning requirements as specified in the certification basis of the aircraft to be installed. A lightning zone analysis and assessment of the effects of lightning strike on the camera in conjunction with other cockpit equipment should be accomplished. The installation must be designed in a manner that lightning strikes on the EVS/SVS/CVS system does not cause catastrophic effects on the aircraft.

5.2 EFVS Display (HUD or Equivalent) Installation Considerations

5.2.1 EFVS Annunciations. Any modes of EFVS operation should be annunciated on the flight deck and visible to the crew. The modes of the EFVS operation must be made available to the flight data recorder as required.

5.2.2 EFVS Display.

5.2.2.1 Display resolution. Since the sensor can be active or passive, the EFVS display should adequately resolve a 60 ft. wide runway from 200 ft. height above touchdown zone elevation with a typical 3-degree glide slope. The pilot needs to be able to detect and accurately identify the visual references in the image.

5.2.2.2 Imagery and symbology display. Imagery must not degrade presentation of essential flight information on the HUD. The pilot's ability to see and use the required primary flight display information such as primary attitude, airspeed, altitude, and command bars must not be hindered or compromised by the EFVS image on the HUD.

5.2.2.3 Flare Cue. An EFVS Landing System must have a flare cue because it is intended to enable landing in low visibility. The flare cue, whether a flare prompt or flare guidance, should demonstrate compliance to the landing criteria found in paragraph 6.2. For some aircraft, flare guidance may be required because a flare prompt is not sufficient.

5.2.2.3.1 Flare Prompt. A flare prompt is intended to notify the pilot that it is time to initiate the flare maneuver, but does not guide the pilot's manual pitch control inputs. The pilot should use situational information (e.g., altitude, vertical rate, attitude, FPV, perspective view of the runway) from the EFVS to judge the magnitude and rate of manual pitch control inputs. The appearance and dynamic behavior of the flare prompt should be distinguishable from command guidance. The flare prompt should appear timely and conspicuously to the pilot using the HUD so that the flare maneuver will be neither too early nor too late and within the touchdown zone as described in paragraph 6.2 of this document.

5.2.2.3.2 Flare Guidance. Flare guidance provides explicit command guidance for the pilot to perform the flare maneuver in so that the flare would be neither too early nor too late and within the touchdown zone as described in paragraph 6.2 of this document.

5.2.3 EFVS Maintenance**.** Instructions for Continued Airworthiness are to be furnished after final design approval (reference 14 CFR § 21.50 and FAA Order 8110.54A).

5.2.4 EFVS Built-in Test (BIT). Provide a BIT capability (or equivalent means) that, at a minimum, limits the exposure time to latent failures in support of the system safety assessment.

5.2.5 EFVS System Safety Design Criteria to support the 14 CFR §§ 23/25/27/29.1309 analysis (as applicable).

5.2.5.1 The overall level of safety of the aircraft is based on installed equipment. A complete system safety analysis (SSA) should be conducted to identify failure modes and classify the hazard levels. To meet the safety criteria, the system design should preclude failures that can cause hazardously misleading information (HMI) to be presented to the pilot or crew, or which can otherwise subsequently cause an unsafe condition. For example, HMI could include information providing attitude, altitude, and distance cues as outside terrain imagery. This demonstration should be accomplished through analysis and engineering tests.

5.2.5.1.1 The EFVS system must perform its intended function for each applicable operation and phase of flight that it would use.

5.2.5.1.2 The normal operation of the EFVS cannot adversely affect, or be adversely affected by other aircraft systems. Annunciate detected malfunctions of the EFVS system and remove the malfunctioning display elements.

5.2.5.2 Appendix B, Table 4 lists the categories of systems and failure probabilities to meet the safety criteria in 14 CFR part 25 airplanes (AC 25.1309-1A). For 14 CFR part 23 aircraft, similar information can be found in 14 CFR § 23.1309 and AC 23.1309-1E. The following additional guidance helps assess the criticality of the EFVS display, including the potential to display HMI:

- AC 25-11B (chapter 4),
- AC 23.1311-1C, and
- AC 27-1B and AC 29-2C, as appropriate for the installation.

5.2.5.3 Validate all alleviating flightcrew actions that are considered in the EFVS safety analysis during testing either for incorporation in the AFM/AFMS or RFM/RFMS limitation section, procedures section or for inclusion in type-specific training.

5.2.6 EFVS Approach System Required Level of Safety to support the 14 CFR §§ 23/25/27/29.1309 analysis (as applicable).

5.2.6.1 When you are designing an EFVS Approach System, establish safety design goals for airworthiness approval. The safety criteria for each phase of flight, including approach and landing systems are defined in terms of accuracy, continuity, availability, and integrity. FAA design guidance provides criteria to determine the overall required level of safety for the aircraft, in any mode of flight, for any combination of failures which can cause an unsafe condition to be fully assessed and categorized. This includes the probability of the pilot(s) to cope with these failures. The hazard level for any aircraft system depends on the ability of the pilot(s) to cope with failures. For failures where the SSA assumes a particular pilot intervention to limit the hazard effects, for example from Catastrophic or Hazardous to Major or Minor, the applicant must show the pilot can be relied on to perform that intervention. For example, the pilot might be assumed to detect a system error because of other displays or view out the window. It should be demonstrated that pilots can detect the error in a timely fashion and not be hazardously misled. The demonstration must validate the proposed hazard classification, as applicable (see Appendix B, Table 4).

5.2.6.2 The applicant should demonstrate a satisfactory safety (failure and performance) level which must not be less than the safety level required for non-EFVS Approach System based precision and non-precision approaches with decision altitudes of 200 ft. or above. In showing compliance, probabilities cannot be factored by the fraction of approaches which are made using EFVS. Consideration, however, can be given to the

EFVS Approach System critical flight time, such as from the highest DH that can be expected for an EFVS Approach System based approach to 100 ft. above the TDZE.

5.2.6.3 The design assurance levels (DALs) are directly linked to the specific intended use and to the specific EFVS Approach System installation as an integrated part of the cockpit flight information system.

5.2.6.4 There are failure modes within the EFVS Approach System which determine that software and hardware DALs should be RTCA/DO-178C (or latest version). In no case should the DAL for EFVS Approach System be less than Level C. However, dependent upon the mitigations for failure conditions in the design, stemming from the specific EFVS and cockpit installations, the DALs can be higher than Level C.

5.2.6.5 The aircraft level functional hazard analysis (FHA) you prepare should determine whether the minimum required DAL level C is adequate for your specific installation. An example FHA is shown in Appendix B, but is a model case only and cannot be applied to any specific aircraft without independent analysis.

5.2.6.6 For general guidance only. An example system safety analysis (SSA) of an EFVS Approach System was performed for a certification on an instrument flight capable aircraft for straight-in landings from non-precision and precision approach and landing operations per 14 CFR § 91.176(b) is shown in Appendix B. The applicant must provide the applicable 14 CFR §§ 23, 25, 27, and 29.1309 analysis that is specific for each installation approval.

5.2.6.7 Conduct a safety analysis to show the EFVS Approach System meets all the integrity criteria for the aircraft, HUD, and EFVS. Demonstrate system and subsystem malfunctions which are not shown to be extremely improbable as appropriate in a simulation or in flight. The malfunction annunciation and fault detection schemes must achieve the determined level of safety.

5.2.7 EFVS Landing System Required Level of Safety to support the 14 CFR §§ 23/25/27/29.1309 analysis (as applicable).

5.2.7.1 The applicant must demonstrate a satisfactory level of safety (failure and performance) appropriate to the operations being addressed, but with the visual segment primarily accomplished by the use of an EFVS Landing System rather than natural vision.

5.2.7.2 To achieve the required safety level, the minimum baseline safety levels required for the installed EFVS Landing System equipment regardless of visibility, should be dependent on the demonstrated performance.

5.2.7.3 An aircraft level Functional Hazard Analysis (FHA) and System Safety Assessment (SSA) should be prepared by the applicant to assess the hazard level associated with system failure conditions and to determine the minimum required software and hardware Design Assurance Levels (DAL) based on the applicant's specific installation. Mitigating system design features include redundancy, independent guidance display, system monitoring, pilot in the loop, pilot not flying, etc. In no case should the DAL be less than DAL C.

5.2.7.4 The minimum required safety level for an EFVS Landing System (EFVS to touchdown and roll out in visibilities not less than RVR 1000 feet) is based on the assumption that the EFVS being certified can demonstrate that the flight crew verify that the aircraft is safely approaching the runway for EFVS Landing System based landing, or, if not, to initiate a timely go around at the RVR level that the applicant is requesting. This provides additional integrity to the operation. Depending on the applicant's design, it may be possible that the proposed visibility can also compensate for loss of EFVS imagery, such that the pilot can use the remaining symbolic flight information on the HUD and the external view to safely land. System evaluation should consider EFVS Landing System failure modes and whether the pilot can safely land and rollout with available natural vision plus whatever remains of EFVS Landing System. In no case should the pilot continue the landing if enhanced or natural vision is not at least that specified in the instrument approach procedure. A Safe landing should not be assumed with only available natural vision after total loss of EFVS Landing System (i.e., symbology and image).

5.2.7.5 In showing compliance with these safety criteria, do not factor probabilities of EFVS Landing System failure conditions by the fraction of approaches which require EFVS Landing System. Also, do not factor probabilities of EFVS Landing System failure conditions by a statistical distribution of visibility conditions. The exposure time used for EFVS Landing System failure calculations should be the elapsed time from descent below the highest expected DA/DH for the EFVS Landing System based approach to completion of rollout to a safe taxi speed.

5.2.8 System Safety Assessment to support the 14 CFR §§ 23/25/27/29.1309 analysis (as applicable).

5.2.8.1 An aircraft level Functional Hazard Analysis (FHA) should be prepared by the applicant to assess the hazard level associated with system failure conditions and to determine that the minimum required software and hardware Design Assurance Levels (DALs) are appropriate to the applicant's specific intended function.

5.2.8.2 The DALs are directly linked to the specific intended use and to the specific EFVS installation as an integrated part of the cockpit flight information system. The availability and integrity of situational and flight path information from sources other than the EFVS image and the ability of the pilot monitoring to monitor the operation should be considered when assessing the appropriate hazard levels for the EFVS.

5.2.8.3 The applicant should provide a System Safety Assessment (SSA) for compliance to the applicable 14 CFR §§ 23/25/27/29.1309 regulation.

5.2.8.4 The safety assessment should show that the applicant's specific installation meets all the integrity criteria for the aircraft systems, and EFVS.

5.2.8.5 The applicant may need to demonstrate by flight test or simulation, combinations of EFVS malfunctions that are not shown to be extremely improbable (10^{-9}).

5.2.8.6 Any malfunction fault detection and annunciation schemes must satisfy the required levels of safety and must perform their intended functions.

5.2.8.7 All aircraft configurations to be certified must be addressed.

5.2.9 EFVS Fail Safe Features. The normal operation of the EFVS may not adversely affect, or be adversely affected by other normally operating aircraft systems. Malfunctions of the EFVS which could cause display of misleading information must be annunciated and the misleading information removed. The criticality of the EFVS's function to display imagery, including the potential to display hazardously misleading information, should be assessed according to 14 CFR 25.1309, AC 25-11B, and AC 25.1309-1A. Likewise, the hazard effects of any malfunction of the EFVS that could adversely affect interfaced equipment or associated systems should be determined and assessed according to 14 CFR 25.1309, AC 25-11B, and AC 25.1309-1A. As applicable, similar criteria are found in 14 CFR 23.1309, and AC 23.1309-1E, 14 CFR § 27.1309 and AC 27-1B and 14 CFR § 29.1309 and AC 29-2C. This requirement must be met through a system safety assessment and documented via FTA, failure mode and effects analysis (FMEA), and failure mode and effects analysis substantiation (FMEA Substantiation), or equivalent safety documentation.

5.2.10 EFVS Environmental Specifications. The EFVS must meet all specified operating criteria and must provide required operating performance, life and reliability when operating within the aircraft and subsystem flight envelope as specified in RTCA/DO-160G (as revised) *Environmental Conditions and Test Procedures for Airborne Equipment*, or future versions. These criteria must also include the HIRF, EMI, and lightning requirements as specified in the certification basis of the aircraft to be installed.

5.3 HIRF Considerations for All Installations (EVS, SVS, CVS, and EFVS).

5.3.1 The immunity of critical avionics/electronics and electrical systems to High-Intensity Radiated Fields (HIRF) must be established. Critical functions are those whose failure would contribute to or cause a failure condition that would prevent the continued safe flight and landing of the aircraft. Refer to AC 20-158A, *The Certification of Aircraft Electrical and Electronic Systems for Operation in the High-Intensity Radiated Fields (HIRF) Environment*, for compatibility with other systems.

5.3.2 New avionics/electronics and electrical systems performing critical functions should be designed and installed to preclude component damage and interruption of function due to both the direct and indirect effects of HIRF. For these systems, compliance must be shown to 14 CFR § 23.1308(a), 25.13l7(a), 27.13l7(a), or 29.1317(a), as appropriate.

Note: AC 20-158A (paragraph 6) provides guidance on Approaches to Compliance.

CHAPTER 6. PERFORMANCE EVALUATION

6.1 EVS/SVS/EFVS Performance Demonstration

6.1.1 The performance demonstration, establishing aircraft system compliance with applicable FAA regulations, typically includes bench testing, simulation flight testing, data collection, and data reduction to show that the proposed performance criteria can be met. Minimal performance standards necessitate an evaluation of the system used during anticipated operational scenarios. The performance evaluations should therefore include demonstrations of taxi, take-off, missed approaches, failure conditions, cross wind conditions, and approaches into specific airports as appropriate for the system's intended function. For EFVS, the applicant should demonstrate performance at the lateral and vertical limits for the type of approach (for example, precision, non-precision, and approach with vertical guidance) for which operational credit being sought. Appendix D provides sample EFVS flight test considerations.

6.1.2 No specific test procedures are cited, as it is recognized that alternative methods can be used. Alternate procedures can be used if it can be demonstrated that they provide all the information needed to show compliance with the applicable regulations. System performance tests as they relate to operational capability are the most important tests. Subsystem tests are used as subsystems are added during system buildup to ensure appropriate subsystem performance as it relates to overall system performance.

6.1.3 The applicant should use any of these four general verification methods (refer to AC 25.1329-1C, AC 23.1309-1E, AC 27-1B or AC29-2C as applicable)

6.1.3.1 Analysis. Demonstrate compliance using an engineering analysis.

6.1.3.2 Flight Test. Demonstrate compliance using an aircraft that is fully representative for the purpose of the test in terms of flight deck geometry, instrumentation, alerts, indications, and controls (in the air or on the ground).

6.1.3.3 Laboratory Test. Demonstrate compliance using an engineering bench representative of the final EVS/SVS/CVS/EFVS system being certified.

6.1.3.4 Simulation. Demonstrate compliance using a flight simulator.

6.1.4 Specify the individual verification methods that you use in the certification plan. Confirm the appropriate certification office agrees with your plan <u>before</u> you begin. For extensions, features, and design decisions not explicitly specified in this AC, conduct human factors evaluations. Conduct these evaluations through analyses, bench, simulation, or flight testing.

6.1.5 Verify both the installed system and the individual system components meet the EVS/SVS/CVS/EFVS criteria described in Chapter 4.

6.1.6 Demonstrate the system meets performance criteria specified in Chapter 4 by flight test and other appropriate means, which can include use of a flight simulator. An example of a flight test program for EFVS is described in Appendix D in this AC. The flight test program assumes that the guidance system utilized to satisfactorily position the aircraft at the DA/DH or MDA has been separately tested and shown to fully perform its intended function. Testing and data collection to demonstrate this is not part of this document.

6.1.7 Airframe and equipment manufacturer based tests or analyses, as applicable, should be developed and conducted to validate the detailed system criteria. No specific test procedures are cited because alternative methods can be used. You can use alternate procedures if you can demonstrate that they provide all the required information. System performance tests as they relate to operational capability are the most important tests. Subsystem tests are used as subsystems are added during system buildup to ensure appropriate subsystem performance as it relates to overall system performance.

6.1.8 Conduct an evaluation of the system used during anticipated operational scenarios.

6.1.9 For EFVS testing: If the aircraft meets all of the applicable airworthiness requirements specified in 14 CFR §§ 91.176(a)(1)(i), (a)(2)(iii), (b)(1)(i), and (b)(2)(iii) does not aply to operations conducted in an aircraft issued an experimental certificate under 14 CFR § 21.191 for the purposes of research and development or showing compliance with regulations, provided that the operations can be conducted safely in accordance with operating limitations issued for that purpose

6.2 Performance Demonstration of EFVS Landing System.

6.2.1 Where appropriate for the performance demonstration, the non-visual conditions can be achieved either by natural obscuration or by use of a visibility limiting device in front of the pilot. Caution should be used if the applicant chooses to use a visibility limiting device for system performance demonstrations. Visibility-limiting devices may not adequately simulate low visibility conditions for all EFVS Landing System landing performance demonstrations because of the unrealistically good external visibility outside the HUD FOV and the unrealistic EFVS Landing System image performance in good atmospheric conditions.

6.2.2 The workload associated with the use of EFVS Landing System for approach, landing and rollout must be considered when showing compliance with 14 CFR §§ 23/25/27/29.1523.

6.2.3 Final approach course offsets greater than 3 degrees will be subject to additional flight test evaluation. The maximum allowable final approach course offset is established by flight test. These tests should include the factors related to the offset, such as HUD/EFVS field of view, crosswinds, and the maximum drift angle for a conformal flight path vector.

6.2.4 The EFVS Landing System image, with superimposed flight symbology, must not mislead, distract or jeopardize the safety of the landing and rollout. Performance shall be demonstrated to be no worse than that normally achieved in visual operations for the specific aircraft for all performance parameters measured. The applicant may propose a valid means for establishing performance normally achieved that the FAA may accept as a benchmark for the EFVS demonstrations.

6.2.5 Benchmark data establishing equivalence to normal visual operations with the specific aircraft would not normally be necessary. However, if flight test results show deviations for the standard criteria listed above, then benchmark data might be used to establish the equivalence of EFVS Landing System operations to normal visual operations for that specific aircraft.

6.2.6 Without requiring exceptional pilot skill, alerting, strength, or workload, the image/symbology should provide the visual cues for the pilot to perform the following items.

6.2.6.1 Speed control within +10/-5 knots of the approach speed, whether manually controlled or with auto-throttle, as proposed by the applicant, up to the point where the throttles are retarded for landing.

6.2.6.2 A smooth transition through flare to landing.

6.2.6.3 Approach, flare, and landing at a normal sink rate for the aircraft.

6.2.6.4 All touchdowns in the touchdown zone. Lateral touchdown performance must be demonstrated to be no worse than that achieved in visual operations for the specific aircraft. Longitudinal touchdown performance must be demonstrated within the touchdown zone which is the first one third, or the first 3000ft, of the usable runway, whichever is more restrictive, and demonstrated to be equivalent or better than that achieved in visual operations for the specific aircraft.

6.2.6.5 Prompt and predictable correction of any lateral deviation away from the runway centerline to smoothly intercept the centerline.

6.2.6.6 Touchdowns with a bank angle that is not hazardous to the airplane.

6.2.6.7 Demonstrated performance of the installed EFVS at representative visibilities for EFVS Approach System and EFVS Landing System operations as described in this document, will determine any additional limitation (for example, crosswind and offset).

6.2.6.8 A normal derotation.

6.2.6.9 Satisfactory and smooth control of the airplane from touchdown to a safe taxi speed.

6.2.6.10 Satisfactory and smooth control of the path of the airplane along the runway centerline through rollout to a safe taxi speed.

6.2.6.11 A safe go around anytime including up to touchdown in all configurations to be certified.

6.3 Environmental Qualification and Design Assurance.

6.3.1 Installed equipment meets the criteria in RTCA/DO-160G (as revised).

6.3.2 Design Assurance.

6.3.2.1 Follow the criteria of RTCA/DO-178C or higher, *Software Considerations in Airborne Systems and Equipment Certification*, to conduct software design assurance tests. The version must be current at time of application.

6.3.2.2 Follow the criteria of RTCA/DO-254, *Design Assurance Guideline for Airborne Electronic Hardware*, to conduct hardware design assurance tests, if applicable. The version must be current at time of application.

APPENDIX A. FAA EFVS 14 CFR COMPLIANCE (PARTIAL LIST)

A.1 Airworthiness Standards.

A.1.1 Certification Procedures for Products and Parts (14 CFR part 21).

A.1.2 Normal, Utility, Acrobatic, and Commuter Category Airplanes (14 CFR part 23).

A.1.3 Transport Category Airplanes (14 CFR part 25).

A.1.4 Normal Category Rotorcraft (14 CFR part 27).

A.1.5 Transport Category Rotorcraft (14 CFR part 29).

A.2 EFVS Compliance.

The following requirements address EFVS and some of them could be in addition to HUD criteria and the basic avionics installation. The amount of new test data can be determined by the individual application, availability, and relevance of data.

Table 3. EFVS Acceptable Methods of Compliance

14 CFR §	Description	Acceptable Method of Compliance
23/25/27/29.143	General controllability and maneuverability	Analysis, Simulation, Flight Test
23/25/27/29.251	Vibration and buffeting	Flight Test
23/25/27/29.301	Loads	Analysis
23/25/27/29.303	Factor of safety	Analysis
23/25/27/29.307	Proof of structure	Analysis
25.561/25.562(c)(5))	Emergency landing conditions; Head Injury Criterion (HIC)	Analysis
25/27/29.571 and 23.573	Damage-tolerance and fatigue evaluation of structure	Analysis

14 CFR §	Description	Acceptable Method of Compliance
25.571(e)	Damage-tolerance and fatigue evaluation of structure(discrete source) evaluation	Analysis and/or Test (See Note)
25.581	Lightning protection	Analysis
23/25/27/29.601	General Design and Construction	Drawing
23/25/27/29.603	Materials	Drawing
23/25/27/29.605	Fabrication methods	Drawing
23/25/27/29.609	Protection of structure	Drawing
23/25/27/29.611	Accessibility provisions	Drawing
23/25/27/29.613	Material Strength properties and material design values	Drawing, Analysis, Test (See Note)
23/25/27/29.619	Special factors	Analysis
23/25/27/29.625	Fitting Factors	Analysis
25.629 (d)(8)	Aeroelastic stability	Analysis, Test
25.631	Bird strike damage	Analysis, or Test if necessary. (Testing should be accomplished unless the analysis shows that the integrity of the original structure has not been compromised by EFVS installation modification.)
23/25/27/29.771	Pilot compartment	Flight Test
23/25/27/29.773	Pilot compartment view	Flight Test
23/25/27/29.777	Flight deck controls	Flight Test

14 CFR §	Description	Acceptable Method of Compliance
23/25/27/29.1301	Function and installation	Ground Test and Flight Test
25.1302	Installed systems and equipment for use by the flightcrew	Analysis, Simulation, Flight Test
23/25/27/29.1309	Equip, systems, and install	Analysis and/or Test and Design data
25.1316	System lightning protection	Analysis and Ground Test
23.1308, and 25/27/29.1317	High-intensity Radiated Fields (HIRF) Protection	Ground Test and Flight Test Analysis/Data
23/25/27/29.1321	Arrangement and visibility	Ground Test and Flight Test
23/25/27/29.1322	Warning, caution, advisory lights	Ground Test and Flight Test
25.1323	Airspeed indicating systems	Flight Test
23/27/29.1335	Flight director systems	Ground Test and Flight Test
23/27.1351	Electrical Systems and Equipment; General	Analysis
25/29.1353	Electrical equipment and installation	Analysis
23/25/27/29.1357	Circuit protective devices	Analysis and Ground Test
23/25/27/29.1381	Instrument lights	Ground Test and Flight Test
23/25/27/29.1419	Ice protection	Analysis
23/25/29.1431(a)(c)	Electronic equipment	Analysis and Ground Test
23/25/27/29.1459(e)	Flight data recorders	Flight test

14 CFR §	Description	Acceptable Method of Compliance
23/25/27/29.1501	Operating Limitations and Information; General	Flight Test
23/25/27/29.1523	Minimum flight crew	Flight Test or Simulation
23/25/27/29.1525	Kinds of operation	Flight Test
23/25/27/29.1529	Instructions for Continued Airworthiness	Design Data
23/25/27/29.1581	Aircraft flight manual; General	Design Data and Flight Test
23/25/27/29.1583	Operating limitations	Flight Test Data
23/25/27/29.1585	Operating procedures	Flight Test Data
26.47	Holders of and applicants for a supplemental type certificate - alterations and repairs to alterations.	Analysis

Note: In some cases, previously approved test data for the aircraft may be resubmitted for compliance, if analysis can establish that the test data remains valid for the aircraft with the new modification.

APPENDIX B. EFVS APPROACH SYSTEM AND EFVS LANDING SYSTEM SAFETY GUIDANCE

B.1 General.

B.1.1 Safety Criteria. Safety criteria for approach and landing systems generally consider four elements: accuracy, continuity, availability, and integrity. These criteria apply to both the external navigation systems as well as airborne navigation equipment. Trajectory management or flight technical error, which can be interpreted as signal structure contributing to roughness, bends and scalloping of ILS-based guidance, should also be considered. They also define how the airspace and aircraft are integrated together to make a safe approach and landing. The FAA developed, in conjunction with the other governments, definitions related to safety and performance for a landing system.

B.1.2 Transport Category Airplanes. For aircraft systems, 14 CFR § 25.1309 defines the safety requirement and AC 25.1309-1A defines the means for verification. The probability of each catastrophic failure condition must be 10^{-9} or less per flight hour considering any mode of flight, any combination of failures causing an unsafe condition, and including the probability of the crew to cope with the failures. The FAA accepts this number to assure a negligible adverse effect on accident rates, and to help reduce them as new systems come on line.

B.1.3 General Aviation or Non-Transport Category Airplanes. Similar information can be found in 14 CFR 23.1309 and AC 23.1309. The relationship among airplane classes, probabilities, severity of failure conditions, and software development assurance levels is found in AC 23.1309-1E.

B.1.4 Rotorcraft. Similar information can be found in 14 CFR § 27.1309 and AC 27-1B and 14 CFR § 29.1039 and AC 29-2C.

B.2 Required Level of Safety.

The required level of safety for any aircraft systems, therefore, depends on the ability of the crew to cope with failures as shown in Table 4, which lists the categories of systems and failure probabilities to meet the safety criteria in 14 CFR parts 23 and 25 airplanes. For part 23 airplanes, similar information can be found in 14 CFR § 23.1309 and AC 23.1309-1E. The relationship among airplane classes, probabilities, severity of failure conditions and software development assurance levels is found in AC 23.1309-1E.

Table 4. Required Level of Safety, 14 CFR part 25 Aircraft

Classification	*Effect*	*Target Probability P*
Minor	Slight reduction in safety margins or functional capabilities. Slight increase in crew workload. Some inconvenience to occupants.	$10^{-3} > P > 1^{-5}$
Major	Significant reduction in safety margins or functional capabilities. Significant increase in crew workload or in conditions impairing crew efficiency. Some discomfort to occupants.	$10^{-5} > P > 1^{-7}$
Hazardous/	Large reduction in safety margins or functional capabilities. Higher workload or physical distress such that the crew could not be relied upon to perform tasks accurately or completely. Adverse effects upon occupants including serious or fatal injury to a relatively small number of occupants other than the flight crew.	$10^{-7} > P > 1^{-9}$
Catastrophic	Failure conditions which would prevent continued safe flight and landing, resulting in multiple fatalities, usually with the loss of the airplane.	$10^{-9} > P$

B.3 Demonstration.

To meet the safety criteria, the EFVS design will be demonstrated through analysis and engineering tests to preclude any critical failure combinations that can cause hazardously misleading information to be presented to the crew, or which can otherwise subsequently cause an unsafe condition. Failures which are self-evident or made obvious to the crew, and with which they can safely cope, need not be specifically monitored.

B.4 State Data.

The aircraft state data are provided by the standard inertial, air data, and radio guidance sensors. The HUD or display processor will be required to be at a sufficient level of safety for the aircraft type and application to detect critical random or common faults that could otherwise cause an unsafe condition. The ability to continue the approach below the standard Category I

DA/DH/MDA/MDH into the visual segment therefore is strictly borne by the pilot, a safety factor already accounted for in the safety analysis for standard Category I operations. The example below in Table 5 is a model case and cannot be applied for any specific aircraft. Functional hazard assessments as required by the FAA are aircraft and systems specific.

Table 5. Example EFVS/HUD Functional Hazard Assessment, 14 CFR part 25 Aircraft, ILS Approaches to 100 ft Height Above Touchdown, RVR 1200 ft

FHA NO.	FAILURE CONDITION	PHASE OF FLIGHT	PILOT ACTION	HAZARD INDEX	OBJECTIVE
1.0	LOSS OF FUNCTION				
1.1	Loss of EFVS imagery on HUD	Taxi and Takeoff Enroute Terminal Arrival Final Approach - Above 100 ft. EFVS height above touchdown zone elevation Go-Around	Crew would revert to standard head-up and/or head down procedures	MINOR	10^{-3}
1.2	Loss of EFVS imagery on HUD	Final Approach - From 100 ft. height above touchdown zone elevation to Landing	Crew would perform a go-around or possibly a minimum flare landing	MINOR	10^{-3}
1.3	Loss of HUD symbology	Taxi and Takeoff Enroute Terminal Arrival Final Approach - Above 100 ft. height above touchdown zone elevation Go-Around	Crew would revert to standard head down procedures	MINOR	10^{-3}
1.4	Loss of HUD symbology	Final Approach - From 100 ft. height above touchdown zone elevation to Landing	Pilot would continue the approach and land	MINOR	10^{-3}

FHA NO.	FAILURE CONDITION	PHASE OF FLIGHT	PILOT ACTION	HAZARD INDEX	OBJECTIVE
1.5	Loss of HUD and EFVS Imagery	Final Approach - From 100 ft. height above touchdown zone elevation to Landing	Pilot would continue the approach and land	MINOR	10^{-3}
2.0	MISLEADING INFORMATION				
2.1	Misleading EFVS imagery on HUD	Taxi Enroute Terminal Arrival Final Approach - Above 100 ft height above touchdown zone elevation Go-Around	Crew would revert to standard head down procedures	MINOR	10^{-3}
2.2	Misleading EFVS imagery on HUD	Final Approach - From 100 ft. height above touchdown zone elevation to Landing	Crew would perform a go-around or possibly a minimum flare landing	MAJOR	10^{-5}
2.3	Misleading HUD symbology	Taxi and Takeoff Enroute Terminal Arrival Final Approach - Above 100 ft. height above touchdown zone elevation Final Approach - From 100 ft. height above touchdown zone elevation to Landing Go-Around	Pilot would take appropriate action as defined in AFM for standard displays and HUD	Various failure conditions with the highest hazard index being MAJOR	Various failure conditions with the highest objective being 10^{-5}
2.4	Misleading EFVS imagery and HUD symbology	Final Approach - Above 100 ft. height above touchdown zone elevation	Copilot would recognize condition using copilot's PFD	MAJOR	10^{-5}

FHA NO.	FAILURE CONDITION	PHASE OF FLIGHT	PILOT ACTION	HAZARD INDEX	OBJECTIVE
2.5	Misleading EFVS imagery and HUD symbology	Final Approach - From 100 ft. height above touchdown zone elevation to Landing	Crew would perform a go-around or possibly a minimum flare landing	MAJOR	10^{-5}
3.0	OBSTRUCTION OF PILOT'S VIEW				
3.1	Obstruction of the pilot's view through the HUD	Takeoff	Pilot would abort takeoff prior to V_1	MAJOR	10^{-5}
3.2	Obstruction of the pilot's view through the HUD	Taxi Enroute Terminal Arrival	Pilot would take appropriate action	MINOR	10^{-3}
3.3	Obstruction of the pilot's view through the HUD	Final Approach - Above 100 ft. height above touchdown zone elevation Go-Around	Pilot would take appropriate action	MAJOR	10^{-5}
3.4	Obstruction of the pilot's view through the HUD	Final Approach - From 100 ft. height above touchdown zone elevation to Landing	Pilot would execute a go-around	MAJOR	10^{-5}

APPENDIX C. EFVS SAFETY STANDARDS

C.1 Safety factors for EFVS described in this AC

Safety standards for the following factors include:

C.1.1 An acceptable degree of interference of the window or "window and HUD" view, potential image misalignment, distortion, and the potential for pilot confusion or misleading information.

C.1.2 Determination of EFVS imagery as flight guidance. The FAA does not intend for the EFVS imagery to be used either as a means of flight guidance/instrument guidance, or as the substitution for the outside view prior to DA/DH or MDA.

C.1.3 Criteria to determine EFVS is of the kind and design appropriate to the following functions:

C.1.3.1 Presenting an enhanced view that would aid the pilot during the approach.

C.1.3.2 Displaying an image that the pilot can use to detect and identify the "visual references for the intended runway" required by 14 CFR § 91.176(b)(3) to continue the approach with vertical guidance to 100 feet height above touchdown (HAT).

C.1.3.3 Depending on the atmospheric conditions and the particular visual references that happen to be distinctly visible and identifiable in the EFVS image, these two functions (found in paragraphs C.1.3.1 and C.1.3.2) would support its use by the pilot to visually monitor the integrity of the approach path.

C.1.3.4 Compliance does not affect the applicability of any of the requirements in the operating regulations (such as 14 CFR parts 91, 121, 125 and 135). The EFVS does not change the approach minima prescribed in the standard instrument approach procedure being used; published minima still apply. (Refer to AC 90-106A for additional information.)

C.2 Features.

C.2.1 The EFVS can be used as a supplemental device to enhance the pilot's situational awareness during any phase of flight or operation in which its safe use has been established.

C.2.2 An EFVS image can provide an enhanced image of the scene that can compensate for any reduction in the clear outside view of the visual field framed by the HUD combiner. The pilot must be able to use this combination of information seen in the image, and the natural view of the outside scene seen through the image, as safely and effectively as the pilot would use a 14 CFR §§ 23/25/27/29.773-compliant pilot compartment view without an EVS image.

C.2.3 14 CFR §§ 23/25/27/29.1301, Equipment: Function and installation, and 14 CFR §§ 23/25/27/29.1309, Equipment, systems, and installations, address certain image characteristics, installation, demonstration, and system safety.

C.2.3.1 Image characteristics criteria include:

- Resolution
- Luminance
- Luminance uniformity
- Low level luminance
- Contrast variation
- Display quality
- Display dynamics (for example, jitter, flicker, update rate, and lag) and
- Brightness controls

C.2.3.2 Installation criteria address:

- Visibility and access to EFVS controls
- Integration of EFVS in the cockpit

C.3 Demonstration.

The EFVS demonstration criteria address the flight and environmental conditions that should to be covered.

C.3.1 The EFVS imagery on the HUD must not degrade the safety of flight, nor interfere with the effective use of outside visual references for required pilot tasks, during any phase of flight in which it is used.

C.3.2 To avoid unacceptable interference with the safe and effective use of the pilot compartment view, the EFVS device should meet the following criteria:

C.3.2.1 The EFVS design should minimize unacceptable display characteristics or artifacts (for example, noise, “burlap” overlay, running water droplets) that obscure the desired image of the scene, impair the pilot's ability to detect and identify visual references, mask flight hazards, distract the pilot, or otherwise degrade task performance or safety.

C.3.2.2 Control of EFVS display brightness should be sufficiently effective, in dynamically changing background (ambient) lighting conditions, to prevent full or partial blooming of the display that would distract the pilot, impair the pilot's ability to detect and identify visual references, mask flight hazards, or otherwise degrade task performance or safety. If automatic control for image brightness is not provided, it should be shown that a single manual setting is satisfactory.

C.3.2.3 The EFVS controls, except those located on the pilot’s control wheel, should be adequately illuminated for all normal background lighting conditions, and should not create any objectionable reflections on the HUD or equivalent display or other flight instruments. There must be a means to allow the pilot using the display to immediately deactivate and reactivate the vision system imagery, on demand, without removing the pilot’s hands from the primary flight and power controls, or their equivalent. (Ref 14 CFR §§ 23.773(c)(3), 25.775(e)(3), 27.773(c)(3), and 29.773(c)(3)).

C.3.2.4 The EFVS image on the HUD should not impair the pilot's use of guidance information nor degrade the presentation and pilot awareness of essential flight information displayed on the HUD, such as alerts, airspeed, attitude, altitude and direction, approach guidance, windshear guidance, TCAS resolution advisories, and unusual attitude recovery cues.

C.3.2.5 The EFVS image should be sufficiently aligned and conformal to both the external scene and conformal HUD symbology so as not to be misleading, cause pilot confusion, or increase workload.

C.3.2.6 The safety and performance of the pilot tasks associated with the use of the pilot compartment view must not be degraded by the display of the EFVS image. Pilot tasks that must not be degraded by the EFVS image include:

- Detection, accurate identification, and maneuvering, as necessary, to avoid traffic, terrain, obstacles, and other hazards of flight.
- Accurate identification and use of visual references required for every task relevant to the phase of flight.

C.3.2.7 Compliance with these criteria does not affect the applicability of any of the requirements in the operating regulations (for example, 14 CFR parts 91, 121, 125, and 135). The criteria must be of a kind and design appropriate to the following functions:

- Present an image to aid the pilot during the approach.
- Display an image that the pilot can use to detect and identify the "visual references for the intended runway" required by 14 CFR § 91.176 to continue the approach to 100 feet height above touchdown (HAT) under EFVS Approach System operations or all the way to touchdown and rollout under EFVS Landing System operations. Appropriate limitations should be included in the Operating

Limitations section of the Airplane Flight Manual to prohibit the use of the EFVS for functions not found to be acceptable.

C.4 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;
- Flight path vector; and
- Flight path angle reference cue.
- Radio altitude (For systems seeking EFVS Landing System credit)
- Flare prompt or flare guidance for aircraft other than rotorcraft (For systems seeking EFVS Landing System credit)

C.5 Head-Up Display. An EFVS used to conduct operations under 14 CFR **§§** 91.176, 121.651, 125.381, and 135.225 must have an FAA type design approval. For a foreign-registered aircraft, the aircraft must meet all of the requirements in 14 CFR § 91.176, including the equipment requirements, in order to be used in EFVS operations in the United States. Under 14 CFR § 91.176, an EFVS is an installed airborne system which includes:

- The display element, which is a 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.
- Controls.

APPENDIX D. SAMPLE EFVS APPROACH SYSTEM FLIGHT TEST CONSIDERATIONS

D.1 General Flight Test Considerations.

D.1.1 The objectives of the flight test program are to ensure that the system performs its intended function when installed, and to demonstrate that the EFVS Approach System is operationally acceptable and safe. The objectives of the flight test program are not to quantitatively measure the detection performance of the sensor. However, for EFVS Approach Systems installed on aircraft that are intended to conduct 14 CFR part 121, 125, and 135 operations the applicant should document the EFVS Approach System's demonstrated performance and the environmental conditions in which the performance was demonstrated. The additional documentation of the system's demonstrated performance is necessary for the 14 CFR part 121,125, and 135 operators to be granted operational approval from Flight Standards to conduct EFVS operations to 100 feet above the TDZE. See AC 90-106A for further information regarding the operational approval process required for conducting EFVS operations to 100 feet above the TDZE.

D.1.2 At the end of the flight test program, the EFVS Approach System should have demonstrated it is capable of imaging the required visual references before they are visible out the window using natural vision. The EFVS should enable descent below DA/DH or MDA using enhanced flight visibility when visual references would not otherwise be visible using natural vision at an altitude no lower than DA/DH or MDA.

D.1.3 The combination of the EFVS Approach System imagery with the HUD symbology and the relationship between the two in terms of brightness and contrast is a critical issue with respect to the installation; therefore, for the purpose of certification flight testing, the environmental conditions chosen should be such that these parameters are adequately evaluated.

D.1.4 Environmental conditions should be chosen to exercise both the automatic and manual control of items such as brightness, contrast, and gain, and any other parameter that affects the image displayed to the pilot.

D.2 Minimum Flight Test Conditions Observed.

D.2.1 Testing should include an appropriate number of fault-free approaches (see note below) in as many of the conditions listed below as practicable and as applicable. Past experience has shown that more than 50 fault-free approaches are needed to demonstrate than an EFVS adequately performs its intended function. The list below should be assessed against the specific sensor type. Additional test conditions can be specified.

- Night VFR conditions over various topography (urban, rural, snow covered, etc.).
- Day and night IFR conditions over various topography.
- Representative levels of rainfall.

- Representative levels of snowfall.
- Representative levels of fog.
- Haze.
- Representative sun angles.
- Representative airport lighting configurations.
- Representative airport/runway surface conditions (dry, wet, standing water, snow cover).
- Representative thermal crossover conditions.
- Representative crosswind and off-set approach course conditions regarding lateral FOR.
- Representative runway surface types (dirt, asphalt, concrete, etc.).
- Representative adjacent surfaces types (dirt, asphalt, concrete, etc.).
- Representative instrument approaches for the intended EFVS operations.

Note: A successful go-around due to lack of either enhanced vision from the DH/DA or natural vision at 100 ft above TDZE, does not constitute a faulted approach. A faulted approach is if:

- HUD or EFVS Approach System failure has occurred.
- At 100 ft above TDZE the indicated airspeed, heading, or attitude are not satisfactory for a normal flare and landing, due to a confusing or misaligned EFVS Approach System image.
- At 100 ft above TDZE the aircraft is not positioned so that the cockpit is within, and tracking so as to remain within, the lateral confines of the runway extended.
- Due to a confusing or misaligned image, the touchdown will be too short or too long.
- The EFVS Approach System image degrades the fly-ability of the display such that a successful approach to DA/DH or MDA/MDH is not possible.

D.3 Test Points

Testing should include all phases of flight for which the applicant seeks approval of the system. In addition to the success criteria for approaches, the EFVS Approach System minimum performance standards require the assessment of the HUD/EFVS Approach System display when used in conjunction with the flight instrumentation required in 14 CFR § 91.176 and listed in chapter 4, paragraph 4.5.1.3 of this AC. The following evaluations should be performed in representative configurations. (The pilot evaluation matrix is at the end of this appendix.)

D.4 Evaluation During Taxi

D.4.1 Assess EFVS Approach System/HUD combination while taxiing and making identification of objects on runways, taxiways, parking aprons.

D.4.2 Verify the use of EFVS Approach System does not cause confusion or misleading information when viewing through the HUD/EVS all types of airport runway, taxiway, obstruction, and barrier lighting, marking and signage as well as the navigation, taxi, and landing lights of other aircraft**.**

D.4.3 Verify the HUD combiner, with the image displayed, does not significantly alter the color perception of the external scene.

D.4.4 Assess lack of burn-in or blooming from high intensity heat sources such as operating (running) engines, etc.

D.5 Take off Evaluation

D.5.1 Ensure correct pitch angle is achieved using HUD pitch reference target.

D.5.2 Verify symbology in EFVS Approach System mode is clear, visible, and does not cause over-control or oscillations in acquiring and maintaining the required ground track.

D.5.3 Confirm the HUD with EFVS Approach System provides the pilot with a quick-glance (instant) sense of flight parameters.

D.5.4 Assess the transition to different selected vertical modes.

D.5.5 Evaluate the EFVS Approach System image during the take-off roll and throughout the climb segment, against the attributes listed in the pilot evaluation matrix.

D.6 Climb and Descent and Lateral Modes Evaluation

D.6.1 Climb, descent, and lateral modes should be evaluated in day and night IMC and VMC to assess HUD/EFVS Approach System compatibility.

D.6.2 During vertical and lateral guidance maneuvers, evaluate the EFVS Approach System image against the attributes listed in the pilot evaluation matrix.

D.7 Instrument Approaches.

During any instrument approach for which approval is sought, HUD/EFVS Approach System compatibility should be evaluated against the attributes listed in the pilot evaluation matrix.

D.8 Flare Landing and Go Around

D.8.1 While using EFVS Approach System during final approach and through the flare (below 50 ft), touchdown roll or go-around, assess the transition to natural vision and compatibility of the guidance when following the HUD/EFVS Approach System flight cues.

D.8.2 Confirm landing rollout information, if provided in the display, is sufficiently visible to the pilot and does not cause over-control or oscillations in acquiring and maintaining the required ground track.

D.8.3 Throughout the approach guidance maneuvers, evaluate the EFVS Approach System image against the attributes listed in the pilot evaluation matrix.

D.9 Copilot Monitor

A copilot monitor is not required by the FAA for operations within the United States. However, if one is installed, the applicant should assess the ergonomic aspects of the image on the copilot's EFVS Approach System monitor.

D.9.1 Verify satisfactory display of imagery in all lighting and environmental conditions and that dimming controls of the display are adequate.

D.9.2 If the display has dual purposes, verify the means of switching the display to being the EFVS Approach System monitor and back is satisfactory and clearly evident.

D.9.3 Verify no flicker and/or jitter in the display.

D.9.4 Verify no objectionable glare or reflections are generated by the display or are visible in the display.

D.9.5 Verify the co-pilot's use of the EFVS Approach System monitor does not require undue head/body movement away from his/her normal scan pattern or his/her normal seated position.

D.10 Failure Cases.

Failure cases to support the FHA should be assessed as required, for example, uncommanded full image brightness, misaligned image, frozen image, etc. during the approaches required in this appendix.

D.11 Ice Protection System Evaluation

D.11.1 If the EFVS Approach System sensor installation has ice protection capability, the EFVS Approach System image must be evaluated with the ice protection on and off in representative environmental conditions.

D.11.2 Icing of the sensor fairing/radome must be appropriately assessed in accordance with the certified flight envelope.

D.12 Evaluation Matrix.

Table 6 contains the pilot's evaluation matrix. The evaluation matrix should be used to support the testing described in this appendix. Additional evaluation points may be added to the test program depending on particular features and intended functions of the actual system being certified.

Table 6. EFVS Approach System Evaluation Matrix

	EFVS Approach System Evaluation Conditions
A	Confirm crew workload is not adversely affected by the HUD/EFVS Approach System installation.
B	Verify no adverse physiological effects from using the HUD/EFVS Approach System (for example, fatigue, eye strain).
C	Verify HUD/EFVS Approach System symbology is visible within pilot Field of View (FOV). (When viewed by both eyes from any off-center position within eye box, non-uniformities should not produce perceivable differences in binocular view.)
D	Verify no jitter or flicker of HUD/EFVS Approach System symbology/image.
E	Verify the EFVS Approach System image does not have noise, local disturbances or artifacts that distract from the use of the system.
F	If HUD symbology has been modified to accommodate the EFVS Approach System image, assess HUD guidance and ensure that introduction of EFVS Approach System does not induce lag in control symbols inducing Pilot Induced Oscillation (PIO).
G	Verify the system is not adversely affected by aircraft maneuvering or changes in attitudes encountered during the referenced environmental conditions.
H	Ensure the required flight and navigation functions applicable for the phase of flight being evaluated are clearly displayed on the HUD with no unacceptable occlusions during testing.
I	Verify the total data presented by the EFVS Approach System imagery and HUD symbology does not over clutter the HUD combiner display area.

	EFVS Approach System Evaluation Conditions
J	Assess the degree of obscuration of the pilot's outside view or field of view through the cockpit window as a result of EFVS Approach System imagery and HUD symbology.
K	Confirm the pilot's ability to detect hazards, maneuver, avoid traffic, terrain or other obstacles, is not impaired or degraded by the display of EFVS Approach System imagery.
L	Confirm there is no discrepancy between the conformal HUD symbols, sensor image, and the outside view through the windshield.
M	Verify outside visibility as viewed through combiner sensor imagery is adequately aligned and conformal to the external scene and HUD symbology.
N	Confirm the EFVS Approach System imagery does not obscure the desired imagery of the scene, impair the pilot's ability to detect and identify visual references, mask flight hazards, or distract the pilot.
O	Assess the ease of operating the HUD with the sensor image displayed, during aircraft maneuvers and change in attitude, encountered in normal operations.
P	Determine whether there is any glare or reflection that could interfere with the EFVS Approach System image either in day or night lighting conditions.
Q	Determine if any impairment is experienced in the ability to use the display due to visible external surfaces within the HUD.
R	Determine whether the sensor image displayed on the HUD combiner objectionably impairs the pilot compartment view.
S	Assess impact of water droplets running across the sensor window to ensure that it does not distract the pilot or degrade his/her task performance or safety.
T	Verify identification of approach lights, runway threshold, touchdown zone etc. as per 14 CFR § 91.176(b)(3).
U	Confirm the HUD EFVS Approach System image is suitable and performs its intended function.
V	Confirm the sensor image on the co-pilot's display (if installed) is useable and performs its intended function.
W	Evaluate the EFVS Approach System image during the takeoff roll and throughout the climb segment, against the attributes listed in the attached pilot evaluation matrix.

	EFVS Approach System Evaluation Conditions
X	During vertical and lateral guidance maneuvers evaluate the EFVS Approach System image against the attributes listed in the attached pilot evaluation matrix.

APPENDIX E. SAMPLE FLIGHT TEST CONSIDERATIONS FOR EFVS LANDING SYSTEM

E.1 General Flight Test Considerations.

E.1.1 The objectives of the flight test program are to ensure that the system performs its intended function when installed, and to demonstrate that the EFVS Landing System is operationally acceptable and safe.

E.1.2 The flight test program should demonstrate that the EFVS Landing System is capable of providing enhanced flight visibility that is no less than the visibility required by the instrument approach, in conditions where actual flight visibility is less than the visibility required by the instrument approach. The EFVS Landing System flight demonstrations should prove that the system provides a satisfactory view of the required visual references for descent below DA/DH even when they are not visible using natural vision. The EFVS Landing System should enable the pilot to complete the instrument approach, landing, and rollout to a safe taxi speed using enhanced flight visibility when visual references would not otherwise be sufficiently visible using natural vision.

E.1.3 For EFVS Landing Systems installed on aircraft that are intended to conduct 14 CFR part 121,125, and 135 operations the applicant should document the demonstrated performance and the environmental conditions in which the performance was demonstrated. The additional documentation is necessary for the 14 CFR part 121,125, and 135 operators to be granted operational approval from Flight Standards to conduct EFVS touchdown and rollout. See AC 90-106 for further information regarding the operational approval process required for conducting EFVS operations. A summary of demonstrated performance and the associated environmental conditions should be documented in the AFM.

E.1.4 The flight test should demonstrate that the EFVS Landing System display of imagery and HUD symbology is satisfactory, so that both elements of information are readable and usable without mutual interference. The flight test should demonstrate that the brightness and contrast levels of the imagery and the symbology can be effectively controlled and provide satisfactory contrast between the two. Since flight deck and external light levels can affect the readability of the EFVS Landing System display and can change significantly throughout the approach and landing operation, the flight test should demonstrate that control of display brightness and contrast in dynamic conditions does not require excessive workload for the pilot.

E.1.5 Environmental conditions should be chosen to exercise both the automatic and manual control of items such as brightness, contrast, and gain, and any other parameter that affects the image displayed to the pilot.

E.2 Minimum Flight Test Conditions Observed.

E.2.1 Testing should include an appropriate number of fault-free approaches and landings in as many of the conditions listed below as practicable and as applicable to the systems intended function. The applicant should plan for no less than 50 fault free approaches and landings, of which at least 5 approaches will be needed to confirm satisfactory go-around performance. A sufficient number of approaches will be needed, with visibility conditions between 2400ft RVR and 1000ft RVR, to demonstrate that the EFVS Landing System can provide at least 2400 ft of enhanced flight visibility and enable the complete low visibility operation. The applicant and the FAA will agree on the minimum number of such approaches, but the number may change depending on demonstration results. The following list should be assessed against the EFVS Landing System Sensor(s), intended use and the specific installation. Additional tests may be specified. The environmental conditions to be tested must be agreed to by the FAA.

- Night VFR conditions over various topography (urban, rural, snow covered, etc.).
- Day and night IFR conditions over various topography.
- Representative levels of rainfall.
- Representative levels of snowfall.
- Representative levels of fog.
- Haze.
- Representative sun angles.
- Representative airport lighting configurations.
- Representative airport/runway surface conditions (dry, wet, standing water, snow covered).
- Representative thermal crossover conditions.
- Representative wind conditions (e.g., crosswind, headwind, tailwind) and off-set conditions regarding lateral field of regard.
- Representative runway surface types (dirt, asphalt, concrete, etc.).
- Representative adjacent surfaces types (dirt, asphalt, concrete, etc.).
- Representative runway widths.
- Representative approach procedures and vertical approach angles.
- Representative runway slopes (within the aircraft limitations).

E.2.2 A faulted approach occurs anytime the pilot is unable to complete a safe and successful approach, landing, rollout, and turnoff within the operational performance parameters detailed in Appendix D, or within additional operational performance standards as may be required by the certifying authority. However, a faulted approach does not occur due to the lack or loss of enhanced visibility due to the atmosphere, so long as a successful missed approach or rejected landing is executed. A faulted approach also does not occur due to ATC intervention, interference from other aircraft, interference from ground vehicles or persons, interference from animals (including birds), or any other reason not relating directly to the EFVS.

E.2.3 Final approach course offsets greater than 3 degrees require further flight test evaluation. The maximum allowable final approach course offset is to be established by flight test. These tests should include factors related to the offset, such as the HUD/EFVS field of view, crosswinds, and the maximum drift angle possible for a conformal flight path vector.

E.3 Test Points.

E.3.1 Testing should include all phases of flight in which EFVS Landing System operation will be permitted, approach types, approach course geometries, and aircraft configurations for which the applicant seeks approval of the system. In addition to the success criteria for the approach, landing, and rollout, the EFVS Landing System minimum performance standards require the assessment of the HUD/EFVS display when used in conjunction with the head up flight indications required in 14 CFR § 91.176 and listed in chapter 4, paragraph 4.5.1.3 of this AC. For effective post-flight analysis and evaluation of the results, past experience has shown that time-stamped video of exactly what is displayed on the HUD are recommended.

E.3.2 The test program should demonstrate that the EFVS Landing System image, with superimposed flight symbology, does not mislead, distract or jeopardize the safety of the landing and rollout. Without requiring exceptional pilot skill, alerting, strength, or workload, the image/symbology should allow and provide the visual cues for the pilot to perform:

E.3.2.1 Speed control within +10/-5 knots of the approach speed, whether manually controlled or with auto-throttle, as proposed by the applicant, up to the point where the throttles are retarded for landing.

E.3.2.2 A smooth transition through flare to landing.

E.3.2.3 Approach, flare, and landing at a normal sink rate for the aircraft.

E.3.2.4 Lateral touchdown performance shall be demonstrated to be the no worse than that achieved in visual operations for the specific aircraft. Longitudinal touchdown performance shall be demonstrated within the first 1/3, or the first 3000 ft, of the runway, whichever is more restrictive, and demonstrated to be no worse than that achieved in visual operations for the specific aircraft.

E.3.2.5 Prompt and predictable correction of any lateral deviation away from the runway centerline to smoothly intercepted the centerline.

E.3.2.6 Touchdowns with a bank angle that is not hazardous to the airplane.

E.3.2.7 Demonstrated performance of the installed EFVS Landing System at the representative RVR/visibility, as described in this document, will determine any additional limitations (for example, crosswind and offset).

E.3.2.8 A normal de-rotation.

E.3.2.9 Satisfactory and smooth control of the airplane from touchdown to a safe taxi speed.

E.3.2.10 Satisfactory and smooth control of the path of the airplane along the runway centerline through rollout to a safe taxi speed.

E.3.2.11 A safe go around anytime including touchdown in all configurations to be certified.

E.4 Evaluation During Taxi

E.4.1 Assess EFVS/HUD combination while taxiing and making identification of objects on runways, taxiways, and parking aprons.

E.4.2 Verify that the use of EFVS Landing System does not cause confusion or misleading information when viewing through the HUD/EFVS Landing System appropriate types of airport runway, taxiway, obstruction, and barrier lighting and signage as well as the navigation, taxi, and landing lights of other aircraft.

E.4.3 Verify the HUD combiner with the image displayed does not significantly alter the color perception of the external scene to an extent which jeopardizes the pilot's ability to distinguish the relevant features of the environment, precluding the performance of any required task.

E.4.4 Assess the impact of burn-in or blooming (if applicable) on the EFVS Landing System image from high intensity heat sources such as running engines, stationary lights, etc.

E.5 Take off Evaluation.

E.5.1 Ensure correct pitch angle is achieved using HUD pitch symbology.

E.5.2 Verify symbology in EFVS Landing System mode is clear, visible, and does not cause over-control or oscillations in acquiring and maintaining the required ground track.

E.5.3 Confirm that the HUD with EFVS Landing System provides the pilot with a quick-glance (instant) sense of flight parameters.

E.5.4 Assess the transition to different selected vertical modes.

E.5.5 Evaluate the EFVS Landing System image during the take-off roll and throughout the climb segment, against the attributes listed in the pilot evaluation matrix.

E.6 Climb and Descent and Lateral Modes Evaluation.

E.6.1 Climb, descent, and lateral modes should be evaluated in day and night IMC and VMC to assess HUD/EFVS Landing System compatibility.

E.6.2 During vertical and lateral guidance maneuvers, evaluate the E(F)VS image against the attributes listed in the pilot evaluation matrix.

E.7 Instrument Approaches to the DA(H)

E.7.1 During any instrument approach for which approval is sought, HUD/EFVS Landing System compatibility should be evaluated against the attributes listed in the pilot evaluation matrix.

E.7.2 Final approach course offsets greater than 3 degrees require further flight test evaluation. The maximum allowable final approach course offset is to be established by flight test. These tests should include the factors related to the offset, such as the HUD/EFVS Landing System field of view, crosswinds, and the maximum drift angle possible for a conformal flight path vector. Since 14 CFR § 91.176 permits EFVS to touchdown for approaches which could be offset up to 15 degrees, flight test evaluation should factor this offset into potential limitations and airworthiness approvals.

E.8 Final Approach from the DA/DH, Flare, Landing and Rollout to Safe Taxi Speed.

E.8.1 While using EFVS Landing System during an enhanced visual final approach and through the flare (below 50ft), touchdown, rollout, and turn-off, assess the performance of the EFVS Landing System image and displayed symbology against the attributes listed in the pilot evaluation matrix.

E.8.2 Confirm that a landing and rollout to a safe taxi speed that is primarily performance based on the EFVS Landing System image and displayed symbology does not cause over-control or oscillations in acquiring and maintaining the required ground track.

E.9 Rejected Landing

Confirm that at any time during the EFVS Landing System based approach between DA/DH and touchdown, a safe rejected landing can be conducted.

E.10 Pilot Monitoring (PM) Display.

E.10.1 Verify the display is location meets the requirements of 14 CFR §§ 23/25/27/29.1321 and any symbology displayed should not adversely obscure the sensor imagery of the runway environment.

E.10.2 Verify satisfactory display of imagery in all lighting and environmental conditions and that dimming controls of the display are adequate.

E.10.3 If the display has dual purposes, verify the means of switching the display to being the EFVS Landing System monitor and back is satisfactory and clearly evident.

E.10.4 Verify that the pilot monitoring use of the PM display monitor does not require undue head/body movement away from his/her normal scan pattern or his/her normal seated position.

E.10.5 Verify the PM display provides a conformal image with the visual scene over the range of aircraft attitudes and wind conditions for each mode of operation. The PM's display should be shown to be acceptable for the pilot monitoring to see and identify visual references and to verify that all visual requirements for the approach and landing are satisfied.

E.11 Failure Cases.

Failure cases to support the FHA shall be assessed and tested as required (e.g., uncommanded full image brightness, misaligned image, frozen image, failed image, etc.) during the approaches required in this appendix.

E.12 Ice Protection System Evaluation.

E.12.1 If the EFVS Landing System sensor installation has ice protection/de-misting capability, the EFVS Landing System image should be evaluated with the ice protection/de-misting on and off in representative environmental conditions.

E.12.2 Icing of the sensor fairing should be appropriately assessed in accordance with the aircraft's certified flight envelope.

E.13 Evaluation Matrix

Table 7 below is the test evaluation matrix that should be used to support the testing described above. Additional evaluation points may be added to the test program depending on particular features and intended functions of the actual system being certified.

Table 7. EFVS Landing System Evaluation Matrix

	EFVS Landing System Evaluation Matrix
A	Confirm that crew workload is not adversely affected by the HUD/EFVS Landing System installation.

	EFVS Landing System Evaluation Matrix
B	Verify no adverse physiological effects from using the HUD/EFVS Landing System (e.g. fatigue, eye strain).
C	Verify HUD/EFVS Landing System symbology is visible within pilot Field of View (FOV). (When viewed by both eyes from any off-center position within eye box, non-uniformities shall not produce perceivable differences in binocular view.)
D	Verify no jitter or flicker of HUD/EFVS Landing System symbology/image.
E	Verify that the EFVS Landing System image does not have noise, local disturbances, or artifacts that distract from the use of the system.
F	If HUD symbology has been modified to accommodate the EFVS Landing System image, assess HUD guidance and ensure that introduction of EFVS Landing System does not induce lag in control symbols inducing PIO.
G	Verify the system is not adversely affected by aircraft maneuvering or changes in attitudes encountered during the referenced environmental conditions.
H	Ensure that the required flight and navigation functions applicable for the phase of flight being evaluated are clearly displayed on the HUD with no unacceptable occlusions during testing.
I	Verify that the total data presented by the EFVS Landing System imagery and HUD symbology does not over clutter the HUD combiner display area.
J	Assess the degree of obscuration of the pilots outside view or field of view through the cockpit window as a result of EFVS Landing System imagery and HUD symbology.
K	Confirm that the pilot’s ability to detect hazards, maneuver, avoid traffic, terrain, or other obstacles, is not impaired or degraded by the display of EFVS Landing System imagery.
L	Confirm that there is no discrepancy between the conformal HUD symbols, sensor image and the outside view through the windshield.
M	Verify that outside visibility as viewed through combiner sensor imagery is adequately aligned and conformal to the external scene and HUD symbology.
N	Confirm that the EFVS Landing System imagery does not obscure the desired imagery of the scene, impair the pilot’s ability to detect and identify visual references, mask flight hazards or distract the pilot.
O	Assess the ease of operating the HUD with the sensor image displayed, during aircraft maneuvers and change in attitude, encountered in normal operations.

	EFVS Landing System Evaluation Matrix
P	Determine whether there is any glare or reflection that could interfere with the EFVS Landing System image external surfaces within the HUD.
Q	Determine if any impairment is experienced in the ability to use the display due to visible external surfaces within the HUD.
R	Determine whether the sensor image displayed on the HUD combiner objectionably impairs the pilot compartment view.
S	Assess impact of water droplets running across the sensor window to ensure that it does not distract the pilot or degrade his/her task performance or safety.
T	Verify identification of approach lights, runway threshold, touchdown zone etc. as per 14 CFR § 91.176(a)(3).
U	Confirm that the HUD EFVS image is suitable and performs its intended function.
V	Confirm the sensor image on the copilot's display is useable and performs its intended function.
W	Evaluate the EFVS image during the takeoff roll and throughout the climb segment, against the attributes listed in evaluation EFVS Landing System Evaluation Matrix.
X	During vertical and lateral guidance maneuvers evaluate the EFVS image against the attributes listed in the EFVS Landing System Evaluation Matrix.
Y	Confirm that the EFVS provides the correct and appropriate visual cues for the pilot to perform the required stabilized approach from the DA(H).
Z	Confirm that approach speed can be controlled within +10/-5kts, both with and without auto-throttle if fitted, up to the point where the throttles are retarded for landing.
AA	Confirm that the EFVS provides the correct visual cues for the pilot to perform a smooth transition through flare to landing.
AB	Confirm that the EFVS provides the correct visual cues for the pilot to perform a flare and landing with a normal sink rate.
AC	Confirm that the EFVS provides the correct visual cues to always allow a consistent touchdown in the defined touchdown zone.
AD	Confirm that the EFVS provides the correct visual cues to allow a consistent touchdown with a bank angle that is not hazardous to the airplane.
AE	Confirm that the EFVS provides the correct the correct visual cues to allow normal

	EFVS Landing System Evaluation Matrix
	derotation.
AF	Confirm that EFVS provides the correct visual cues to allow satisfactory and smooth control of the airplane from touchdown to a safe taxi speed.
AG	Confirm that the EFVS provides the correct visual cues to allow prompt and predictable correction of any lateral deviation away from the runway centerline to smoothly intercept the centerline.
AH	Confirm that the EFVS provides the correct visual cues to allow satisfactory and smooth control of the path of airplane along the runway centerline through rollout to a safe taxi speed before reaching the stop at the end of the runway.

APPENDIX F. SAMPLE AIRPLANE FLIGHT MANUAL (AFM) SUPPLEMENT

Note: Appendix F presents a sample for the AFM supplement for STC installations. This example may not be entirely applicable to airplane manufacturers when SVS, EVS, CVS, or EFVS are approved with the type certificate. The ACO will assist the applicant in developing an appropriate Rotorcraft Flight Manual Supplement (RFMS).

Installation Center/Repair Station Model XXX EVS/SVS/EFVS

123 Fourth Street Vision System

Anytown, USA

FAA APPROVED AIRPLANE FLIGHT MANUAL SUPPLEMENT

ABC MODEL XXX YYY VISION SYSTEM

AIRPLANE MAKE:

AIRPLANE MODEL:

AIRPLANE SERIAL NO.:

REGISTRATION NO.:

This document must be carried in the airplane at all times. It describes the operating procedures for the ABC Model XXX YYY vision system when it has been installed in accordance with <*manufacturer's installation manual number and date*>.

For airplanes with an FAA Approved Airplane Flight Manual, this document serves as the FAA Approved ABC Model XXX YYY Flight Manual Supplement. For airplanes that do not have an approved flight manual, this document serves as the FAA Approved ABC Model XXX YYY Supplemental Flight Manual.

The information contained herein supplements or supersedes the basic Airplane Flight Manual dated <*insert date*> only in those areas listed herein. For limitations, procedures, and performance information not contained in this document, consult the basic Airplane Flight Manual.

FAA APPROVED

____

Title
Office
Federal Aviation Administration
City, State

SAMPLE AIRPLANE FLIGHT MANUAL (Continued)

Installation Center/Repair Station Model XXX EVS/SVS/EFVS

123 Fourth Street Vision System

Anytown, USA

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Date: ________

SAMPLE AIRPLANE FLIGHT MANUAL (Continued)

Installation Center/Repair Station Model XXX EVS/SVS/EFVS

123 Fourth Street Vision System

Anytown, USA

SECTION 1 - GENERAL

<Include the appropriate statement to describe the equipment capability:>

EVS: The installed ABC Enhanced Vision System meets with AC 20-167A performance criteria for <*situation awareness*>.

SVS: The installed ABC Synthetic Vision System meets with AC 20-167A performance criteria for <*situation awareness*>.

EFVS Approach System: The demonstrated performance of the installed EFVS Approach System meets the criteria of AC 20-167A for EFVS operations conducted in accordance with 14 CFR § 91.176(b).

During certification flight test, the maximum final approach course offset angle at which the installed EFVS was demonstrated to be used in lieu of natural vision to descend below DA/DH or MDA and complete a landing in accordance with 14 CFR § 91.176(b) was <*insert angle in degrees*>.

<For aircraft that are to be operated under 14 CFR part 121, 125, or 135 should include the statement below that describes the performance of the EFVS Approach system demonstrated during the certification test program.>

The installed EFVS Approach System demonstrated satisfactory approaches in the weather conditions listed below:

<Insert summary statement describing the sensor performance and the lowest visibilities and applicable environmental conditions for which the EFVS Approach System has demonstrated satisfactory landing in accordance with 14 CFR § 91.176 (b).>

EFVS Landing System*:* The demonstrated performance of the installed EFVS Landing System meets the criteria of AC 20-167A for EFVS operations conducted in accordance with 14 CFR § 91.176(a) in visibility conditions sufficient to safely complete the rollout without EFVS function. The demonstrated performance of the installed EFVS also meets the criteria of AC 20-167A for EFVS operations to 100 feet above the TDZE conducted in accordance with 14 CFR § 91.176(b).

The maximum final approach offset angle satisfactorily demonstrated during certification flight test was <*insert angle in degrees*>.

The installed EFVS Landing System demonstrated satisfactory landings in the weather conditions listed below:

<Insert summary statement describing the sensor performance and the lowest visibilities and applicable environmental conditions for which the EFVS Landing System has demonstrated satisfactory landing in accordance with 14 CFR § 91.176 (a).>

SECTION 2 - LIMITATIONS

1. The ABC Model XXX YYY Quick Reference Guide, P/N <*insert part number*>, dated <*insert date*> (or later appropriate revision) must be immediately available to the flight crew whenever navigation is predicated on the use of the system.

2. The system must utilize software version <*insert version identification*>.

3. A valid and compatible database must be installed and contain current data.

4. <*Specify any additional limitations applicable to the particular installation.*>

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Date: ________

SECTION 3 - EMERGENCY/ABNORMAL PROCEDURES

EMERGENCY PROCEDURES

No Change

ABNORMAL PROCEDURES

1. If ABC Model XXX YYY vision system information is not available or invalid, utilize remaining operational navigation equipment as appropriate.

2. If Loss of Integrity Monitoring message is displayed, revert to an alternate means of navigation appropriate to the route and phase of flight or periodically cross-check the GPS guidance to other, approved means of navigation.

SECTION 4 - NORMAL PROCEDURES

1. Normal operating procedures are outlined in the ABC Model XXX YYY Pilot's Guide.

2. System Annunciators <*applicable to installations with external annunciators*>.

3. System Switches <*applicable to installations with external switches*>.

4. Pilot's Display <*describe the pilot's display(s)*>.

5. Flight Director/Autopilot Coupled Operation <*describe any procedures for integrated flight director and/or autopilot system(s)*>.

6.<*Include any other normal operating procedures as necessary.*>

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Date: ________

SECTION 5 - PERFORMANCE

No Change

SECTION 6 - WEIGHT AND BALANCE

<*Refer to revised weight and balance data, if applicable.*>

SECTION 7 - SYSTEM DESCRIPTION

<*Provide a brief description of the system, its operation, installation, etc.*>

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Date: ________

APPENDIX G. INSTALLATION OF ENHANCED VISION SYSTEM AND OR/SYNTHETIC VISION SYSTEM ON ROTORCRAFT

G.1 General.

This appendix provides guidelines for the installation of EVS and/or SVS installed in Rotorcraft as non-required safety enhancing equipment. To promote standardization installation of non-required safety enhancing equipment, a policy memo was published to address a means of compliance for the installation of non-required safety enhancing equipment. Contact the appropriate FAA office responsible for rotorcraft standards for guidance. Also refer to AC 27-1B and AC 29-2C for certification guidance.

G.2 Applicability.

There are unique aspects to rotorcraft that do not apply to fixed wing aircraft. Rotorcraft typically operate at altitudes much closer to the ground and obstacles than fixed-wing aircraft. Additionally, they are inherently unstable and, without a stabilization system, require hands-on control at all times accompanied by constant visual scans to keep them oriented correctly. There are advantages and disadvantages to presenting EVS or SVS information to the pilot. Particular issues of concern are the compelling nature of the display used in a VFR see-and-avoid environment, the presentation of misleading information relating to aircraft location relative to hazards (particularly in night operations), and the installation of EVS/SVS/CVS displays that interact with automated flight control systems and flight guidance systems.

G.3 Airworthiness Approval.

For rotorcraft, the FAA has determined that installation of EVS/SVS/CVS on a primary flight display, either ADI or NAV display, requires ACO involvement through the STC process, under FAA Order 8900.1, Volume 4, Chapter 9 “Selected Field Approvals,” Figure 4-68, Major Alterations Job Aid. Installations on a primary flight display will involve human factors evaluations and flight test evaluations.

G.4 Design Considerations.

The FHA developed for the system should define the hazards of presenting misleading information to the pilot, and loss of an SVS/EVS feature. The system should be designed accordingly. The hazard classification will be based on display location, intended function of the system features, and phase of flight. The hazard classification of misleading information for SVS/EVS/CVS on the primary flight displays will be higher than the classification of misleading information on a display outside the pilot’s primary field of view. For example, the hazard classification of misleading information may be lower if the SVS/EVS/CVS is placed on ancillary displays not used for the display of flight information and not in the pilot’s primary field of view. Additionally, see Appendix H of this AC for further guidance. However for rotorcraft the FAA does not accept “situation awareness only” information on primary flight displays (either

PFD or MFD’s within the pilot’s primary field of view). Therefore the intended function of the SVS/EVS/CVS should be defined. If HTAWS or HTAWS-like features are incorporated, see TSO-C194 HTAWS

APPENDIX H. ADDITIONAL PART 23 CONSIDERATIONS FOR ENHANCED VISION SYSTEM/OR SYNTHETIC VISION SYSTEM FOR SITUATION AWARENESS ONLY

H.1 Introduction.

Synthetic vision may be so compelling that pilots may try to use it beyond the intended function. Current synthetic vision systems may not offer the depth/distance cueing necessary to be used for terrain avoidance. Another way of saying this is that error margins may still be too large to use any synthetic vision system alone. Current systems should be used with approved flight and navigation information. If other systems are not included to augment the synthetic vision system for terrain awareness, the applicant should show that the error margins due to field of view size, depth perception, resolution of the database used, resolution of the display, update rate of the display, and any other factors are small enough that synthetic vision alone is adequate for terrain awareness in all flight conditions expected. Display size constraints may result in a “compressed” display that has the potential to cause misleading altitude and range estimation. In addition, cumulative errors from GPS, terrain databases, and barometric altimetry systems may contribute to misleading distance and height cues. Adequate mitigation should be provided to avoid the effects of such hazards. Such mitigation may be incorporated in the design or may include training or procedures to use other navigation sources. However, it is unwise to depend solely on Aircraft Flight Manual (AFM) limitations.

H.2 Terrain Alerting.

Any airplane equipment incorporating a synthetic vision system should also provide some type of terrain warning for pilots. The terrain warning feature should be incorporated on the Multifunction Display (MFD) or separate display unless the applicant can demonstrate that the feature is effective on the PFD. Synthetic vision systems on the PFD should provide adequate altitude and distance cues if used for terrain warning.

H.2.1 Applicants may use TSO-C151c, Class A, B, or C standards as applicable. Applicants may develop their own terrain warning system. However, the option of developing a terrain warning system is only available when there is not a specific carriage requirement for TAWS or HTAWS; it is not a substitute for any TAWS or HTAWS regulatory requirement. Applicants who want to develop their own terrain warning system should include:

- A one-minute caution and 30-second warning if the airplane’s current flight path will collide with terrain or an obstacle.
- Aural call-out for both the caution and the warning (CAUTION – TERRAIN, TERRAIN; WARNING – TERRAIN, TERRAIN).
- Terrain impact region highlighted on the moving map.

- A safety margin or buffer of at least 100 feet for cumulative errors in both the GPS altitude and terrain database.
- A terrain database/DEM developed using the criteria in RTCA DO-200A, *Standards for Processing Aeronautical Data,* dated September 28, 1998.
- The synthetic vision display must not provide any information that is in conflict with or incompatible with either the terrain warning or terrain awareness functions of the TAWS or HTAWS.

H.3 Moving Map Display that Corresponds to and Complements Synthetic Vision PFD Display.

H.3.1 Synthetic vision depictions on the PFD have the potential to provide pilots with enhanced terrain and landmark awareness during non-precision and precision approaches. However, the display may not provide depth perception and may not provide a field-of-view for pilots to know what is to the left and right of the display view area. When viewing the terrain on a limited field-of-view display, pilots may mistakenly infer the location of the aircraft relative to the terrain.

H.3.2 There should be a second, complementary plan view display. The second display should depict the same terrain, obstacles, and features that appear on the PFDs synthetic vision display. This complementary display mitigates the lack of depth perception and FOV limitations on the typical synthetic vision display. This display should be the navigation display, but it could also be an MFD or a third, separate display. Ideally, the TAWS OR HTAWS or terrain alerting system should be part of this display (unless incorporated into the PFD) so that hazardous terrain or obstacles are highlighted.

H.4 Minimums Audio Callout Capability.

Applicants are encouraged to incorporate either a pilot selectable or automatic altitude alert with audio callout to remind pilots they are approaching minimums. Pilots may "see" the runway environment on their synthetic vision display and continue below minimums inadvertently because they were so intent on following the approach guidance. This scenario is similar to pilots fixating on a flight director and descending below minimums. Alerting pilots that they are nearing minimums reduces the opportunity for this situation to occur.

H.5 Digital Evaluation Model (DEM) Resolution.

The DEM resolution is one factor that determines how well the synthetic vision terrain depiction will match the terrain environment. NASA experiments have shown that a terrain resolution of 30-arc-seconds "rounds off" the terrain peaks and fills in valleys. This makes the terrain appear less hazardous for the peaks than it is and potentially reduces some safety benefit. Conversely, for the valleys, the terrain appears higher and is therefore conservative. The same set of NASA experiments pointed out that even though pilots preferred terrain created using higher resolutions (one and three-arc-seconds), a synthetic vision display using a 30-arc-second database could provide more situation awareness (and, therefore, safety) than the conventional instrument panel. Therefore, we had historically considered 30-arc-second resolution the minimum safety standard for synthetic vision displays. This allowed for the introduction of synthetic vision systems given the technology limitations. But technology has surpassed the need to allow as low a minimum resolution. New systems should meet 15 arc sec or better. Current systems do very well at twice the resolution minimum, but we want to encourage applicants to use the highest resolutions available in unclassified databases. Applicants may also consider using very high resolution databases near airports while reducing the resolution in the rest of the database. More importantly, applicants should clearly define the resolution and measuring units of the DEM used by their synthetic vision system in the AFMS and the pilots' handbooks so that pilots can understand any visual limitation caused by resolution limits.

Note: The DEM resolution needed on a synthetic vision display depends on the intended function of that display. Applicants need to consider how they are going to use the terrain database information for their synthetic vision display, and this information should be given to the FAA at the beginning of a synthetic vision certification program. Common elevation references are average elevation, maximum elevation, and sometimes, the elevation of the geometric center of the area. As post-spacing increases, the difference between the DEM value and the actual elevation of a point within a cell may differ significantly. The elevations used for a synthetic vision display should be conservative; use the highest elevation for a given cell. This concept is identical to the current sectional charts labeling the highest elevation in the given quadrangle (square sector) of latitude and longitude.

H.6 Aircraft Flight Manual Supplement (AFMS).

The AFMS should contain limitations for pilots on use of the applicant's system. These limitations should be explained in detail. Warnings, cautions, and notes should also address the proper use and potential misuse of the display for terrain awareness and avoidance.

H.7 SVS Unusual Attitude Recovery.

Historically, the FAA required all but essential flight information is removed from the PFD in unusual attitudes. This "decluttering" was meant to aid pilots in recovering the aircraft. Therefore, the first synthetic vision systems removed the synthetic depiction and reverted to the traditional "blue-over-brown" display during unusual attitudes. Based on a past report, the FAA Civil Aeronautical Medical Institute (CAMI) observed little performance difference between recoveries with and without the synthetic depiction. Furthermore, there was a possibility pilots might be temporarily confused by the significant change to their primary attitude display. Therefore, applicants should consider leaving the synthetic vision depiction on the PFD for unusual attitude recovery. The SVS update rate will be evaluated in flight test against FAA Practical Test Standard maneuvers.

H.7.1 Some indication of both sky and ground should always be visible on the PFD for use in initiating unusual attitude recovery.

H.7.2 Pilots should be able to initiate a recovery toward the correct horizon and altitude within one second of recognition.

Note: For example, a test scenario could include climbing with a large mountain or plateau in the background into a stall condition or descending into rising terrain with decreasing airspeed into a stall condition.

H.7.3 The artificial horizon line and other attitude-relate symbology (for example, aircraft symbol and pitch ladder) should be very prominent and highly visible against all possible backgrounds and symbology, including the assignment of a level of priority over other symbology on the display commensurate with its importance.

H.8 Pilot Evaluation.

There are hundreds of variables that can distinguish one display system from another. Depending on the design implementation, a synthetic vision system might not provide a safety improvement. Because of the number of variables, a thorough FAA pilot evaluation will be necessary for the first implementation of any synthetic vision display system. Less FAA involvement may be possible on subsequent installations or system upgrades. Often, it is useful to gather subjective pilot assessments of the synthetic vision displays. Questionnaires used with flight evaluations and/or simulation are good tools to use for pilot assessment, but they need to be specific rather than merely solicit general impressions. Accepted and proven evaluation protocol, measures, and scales should be used where applicable to ensure the integrity of the evaluation process. The questions should target specific information presented on the display, its intended function, and whether it is usable for flight tasks required for typical instrument and commercial ratings. Besides using FAA pilots (including Designated Engineering Representative (DER) pilots), the applicant should consider conducting assessments with representative end user/operational pilots. Applicants should coordinate plans for any pilot evaluation with the responsible ACO.

APPENDIX I. DEFINITIONS AND ACRONYMS

I.1 Definitions

I.1.1 **Appliance** (14 CFR § 1.1) - Any instrument, mechanism, equipment, part, apparatus, appurtenance, or accessory, including communications equipment, that is used or intended to be used in operating or controlling an aircraft in flight, is installed in or attached to the aircraft, and is not part of an airframe, engine, or propeller.

I.1.2 **Approach Lighting Designators**

- ALSF-I: High Intensity Approach Lighting System with Sequenced Flashing Lights, Category I Configuration.
- ALSF-II: High Intensity Approach Lighting System with Sequenced Flashing Lights, Category II Configuration.
- MALSR: Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights
- SSALR: Simplified Short Approach Lighting System with Runway Alignment Indicator Lights.
- MALSF: Medium Intensity Approach Lighting System with Sequenced Flashing Lights.
- RAIL: Runway Alignment Indicator Lights (RAIL).
- SF: Sequenced Flashing Lights (SF).

I.1.3 **Combined Vision System (CVS)** - A system which combines information from an enhanced vision system and a synthetic vision system in a single integrated display.

I.1.4 **Command Guidance** - Symbolic information that directs the pilot to follow a course of action to control attitude or thrust in a specific situation (for example, flight director).

I.1.5 **Conformal** (AC 25-11B) - Refers to displayed graphic information that is aligned and scaled with the outside view.

I.1.6 **Decision Altitude** (14 CFR § 1.1) - A specified altitude in an instrument approach procedure at which the pilot must decide whether to initiate an immediate missed approach if the pilot does not see the required visual reference, or to continue the approach. Decision altitude is expressed in feet above mean sea level.

I.1.7 **Decision Height** (14 CFR § 1.1) - A specified height above the ground in an instrument approach procedure at which the pilot must decide whether to initiate an immediate missed approach if the pilot does not see the required visual reference, or to continue the approach. Decision height is expressed in feet above ground level.

I.1.8 **Ego-centric** - Used to define the view of a display image that correlates to inside the aircraft. One example is what the flight crew would see out the window from a forward facing perspective.

I.1.9 **Enhanced Flight Visibility (EFV)** (14 CFR § 1.1) - The average forward horizontal distance, from the cockpit of an aircraft in flight, at which prominent topographical objects can be clearly distinguished and identified by day or night by a pilot using an enhanced flight vision system.

I.1.10 **Enhanced Flight Vision System (EFVS)** (14 CFR § 1.1) - An installed aircraft system which uses 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, including but not limited to forward-looking infrared, millimeter wave radiometry, millimeter wave radar, and/or low light level image intensification. An EFVS includes the display element, sensors, computers and power supplies, indications, and controls.

I.1.11 **Enhanced Vision System (EVS)** - 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, millimeter wave radiometry, millimeter wave radar, low light level image intensifying.

Note 1: EASA uses term "EVS" as equivalent to FAA description of "EFVS."

Note 2: Unlike an EFVS, an EVS does not necessarily provide the additional flight information/symbology required by 14 CFR § 91.176, might not use a head-up display or an equivalent display, and might not be able to present the image and flight symbology in the same scale and alignment as the outside view. This system can provide situation awareness to the pilot, but does not meet the regulatory requirements of 14 CFR § 91.176. As such, an EVS cannot be used as a means to determine enhanced flight visibility or to identify the required visual references and descend below the minimum descent altitude (MDA) or decision height (DH).

I.1.12 **Equivalent Display** - In the context of 14 CFR § 91.176, a display which has at least the following characteristics:

- A head-up presentation not requiring transition of visual attention from head down to head up.
- Displays sensor-derived imagery conformal (as defined in SAE AS 8055) with the pilots external view.
- Permits simultaneous view of the EFVS sensor imagery, required aircraft flight symbology, and the external view.
- Display characteristics and dynamics are suitable for manual control of the aircraft.

I.1.13 **Exocentric** - Used to define the view of a display image that correlates to outside the aircraft. One common exocentric view would be a North Up Plan view shown on moving map displays.

I.1.14 **Eye Reference Point (ERP)** - The ERP is the point in the cockpit that allows for a finite reference enabling the precise determination of geometric entities that define the layout of the cockpit and displays.

I.1.15 **Field of Regard (FOR)** (SAE ARP 5677) - The angular extent of the external world that is represented on a display.

I.1.16 **Field of View (FOV)** - The angular extent of the display that can be seen by either pilot with the pilot seated at the pilot's station. AC 25-11B provides the following diagram for primary field of view. See Figure 4 below.

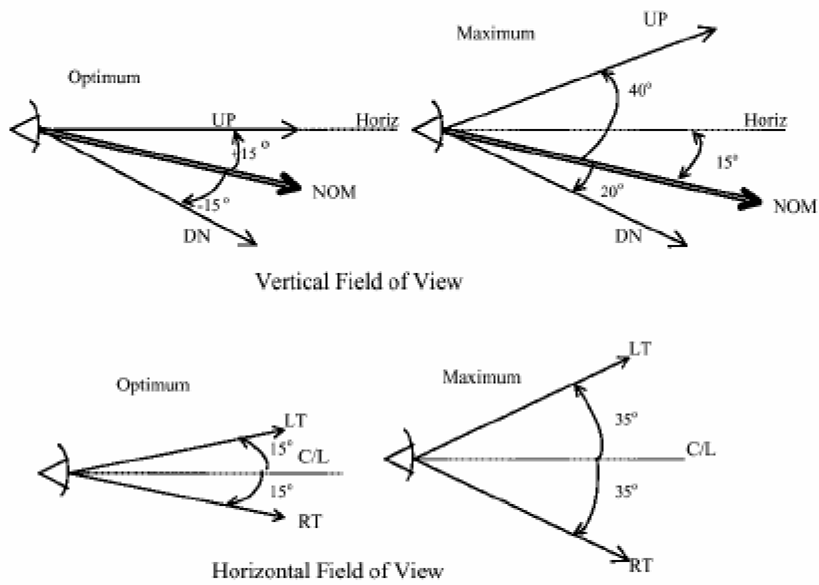

Figure 4. Field of View

I.1.17 **Flare Guidance** - Provides explicit command guidance for the pilot to flare the aircraft.

I.1.18 **Flare Prompt** - The flare prompt advises the pilot when it is time to begin making the control inputs for the flare maneuver and transition to landing. A flare prompt does not provide command guidance for maneuver the airplane with regard to the rate or magnitude of manual inputs, alignment to runway heading nor touching down at a specific point on the runway.

I.1.19 **Flicker** (RTCA/DO-315A) - High frequency luminance variations.

I.1.20 **Flight Path Angle Reference Cue** - Pilot selectable reference cue on the pitch scale displaying the desired approach angle.

I.1.21 **Flight Path Vector** - A symbol on the primary display (HUD or PFD) that shows where the aircraft is actually going, the sum of all forces acting on the aircraft.

I.1.22 **Flight Visibility** (14 CFR § 1.1) - The average forward horizontal distance, from the cockpit of an aircraft in flight, at which prominent unlighted objects can be seen and identified by day and prominent lighted objects can be seen and identified by night.

I.1.23 **Head Up Display (HUD)** (AC 25.1329-1C) - A transparent optical display system located level with and between the pilot and the forward windscreen. The HUD displays a combination of control, performance, navigation, and command information superimposed on the external field of view. It includes the display element, sensors, computers and power supplies, indications and controls. It is integrated with airborne attitude, air data and navigation systems, and as a display of command information is considered a component of the flight guidance system.

I.1.24 **IFR conditions** (14 CFR § 1.1) - Weather conditions below the minimum for flight under visual flight rules.

I.1.25 **Instrument** (14 CFR 1.1) - A device using an internal mechanism to show visually or aurally the attitude, altitude, or operation of an aircraft or aircraft part. It includes electronic devices for automatically controlling an aircraft in flight.

I.1.26 **Jitter** (RTCA/DO-315A) - High frequency positional oscillations.

I.1.27 **Latency** (AC 25-11B) - The time taken by the display system to react to a triggered event coming from an input/output device, the symbol generator, the graphic processor, or the information source.

I.1.28 **Minimum Descent Altitude** (14 CFR § 1.1) - The lowest altitude, expressed in feet above mean sea level, to which descent is authorized on final approach or during circle-to-land maneuvering in execution of a standard instrument approach procedure, where no electronic glide slope is provided.

I.1.29 **Noise Equivalent Power (NEP)** - Measure of the sensitivity of an optical detector or detector system.

I.1.30 **Noise Equivalent Temperature Difference (NETD)** - A measure of the sensitivity of a detector of thermal radiation in the infrared, terahertz radiation, or microwave radiation parts of the electromagnetic spectrum.

I.1.31 **Non-Uniformity Correction (NUC)** - Calibration of a detector utilizing more than one detector element.

I.1.32 **Precision Approach Procedure** (14 CFR § 1.1) - A standard instrument approach procedure in which a precision lateral and vertical path is provided.

I.1.33 **Primary Flight Display (PFD)** - The displays used to present primary flight information.

I.1.34 **R_{max}. -** The maximum range the radar can detect.

I.1.35 **Situation Information** (AC 120-29A, *Criteria for Approval of Category I and Category II Weather Minima for Approach*,) - Information that directly informs the pilot about the status of the aircraft system operations or specific flight parameters including flight path.

I.1.36 **Synthetic Vision** (14 CFR § 1.1) - A computer-generated image of the external scene topography from the perspective of the flight deck that is derived from aircraft attitude, high-precision navigation solution, and database of terrain, obstacles and relevant cultural features.

I.1.37 **Synthetic Vision System (SVS)** (AC 25.1329-1C) - An electronic means to display a computer-generated image of the applicable external topography from the perspective of the flight deck that is derived from aircraft attitude, altitude, position, and a coordinate-referenced database.

Note: "Topography" defined as maps or charts of natural and man-made features of a place or region especially in a way to show their relative positions and elevations, as applicable whenever deemed appropriate and practicable.

I.1.38 **Thermal Crossover** - The natural phenomenon that normally occurs twice daily when temperature conditions are such that there is a loss of contrast between two adjacent objects on infrared imagery.

I.1.39 **Threshold Crossing Height (TCH)** (Pilot/Controller Glossary) - The theoretical height above the runway threshold at which the aircraft's glideslope antenna would be if the aircraft maintains the trajectory established by the mean ILS glideslope.

I.1.40 **Visual References** - Visual information the pilot derives from the observation of real-world cues, out the flight deck window, used as a primary reference for aircraft control or flight path assessment.

I.2 Acronyms.

Acronym	Phrase
AC	Advisory circular
ACO	Aircraft certification office
AFM	Aircraft flight manual
BIT	Built in test
CVS	Combined vision system
DA	Decision altitude
DEM	Digital elevation model
DH	Decision height
DTED	Digital terrain elevation data
EASA	European Aviation Safety Agency

Acronym	**Phrase**
EFB	Electronic flight bag
EFIS	Electronic flight instrument system
EFVS	Enhanced flight vision system
EMI	Electromagnetic interference
EVS	Enhanced vision system
FAA	Federal Aviation Administration
FHA	Functional hazard analysis
FLIR	Forward looking infrared
FMEA	Failure mode and effects analysis
FOR	Field of regard
FOV	Field of view
FTA	Fault tree analysis
HAT	Height above touchdown
HDD	Head-down display
HIRF	High intensity radiated fields
HMI	Hazardously misleading information
HTAWS	Helicopter terrain awareness and warning system
HUD	Head-up display
IFR	Instrument flight rules
ILS	Instrument landing system
MDA	Minimum descent altitude
MDH	Minimum descent height
MFD	Multi-function display
ND	Navigation display
NETD	Noise equivalent temperature difference
NUC	Non-uniformity correction
PFD	Primary flight display
PIO	Pilot Induced Oscillation
RFM	Rotorcraft flight manual
RVR	Runway Visual Range
SSA	System safety analysis
STC	Sensitivity time control; supplemental type certificate
SVS	Synthetic vision system
TAWS	Terrain awareness and warning system
TC	Type certificate
TCH	Threshold crossing height
TDZE	Touchdown zone elevation

APPENDIX J. RELATED PUBLICATIONS

J.1 Related Publications.

J.1.1 FAA Documents:

J.1.1.1 Order 8110.4C, Type Certification.

J.1.1.2 Order 8110.54A, Instructions for Continued Airworthiness Responsibilities, Requirements, and Contents.

J.1.1.3 AC 23-18, Installation of Terrain Awareness and Warning System (TAWS) Approved for Part 23 Airplanes.

J.1.1.4 AC 23.1309-1E, System Safety Analysis and Assessment for Part 23 Airplanes.

J.1.1.5 AC 23.1311-1C, Installation of Electronic Display in Part 23 Airplanes.

J.1.1.6 AC 25-11B Electronic Flight Deck Displays.

J.1.1.7 AC 25-23, Airworthiness Criteria for the Installation Approval of a Terrain Awareness and Warning System (TAWS) for Part 25 Airplanes.

J.1.1.8 AC 25.571-1D Damage Tolerance and Fatigue Evaluation of Structure

J.1.1.9 AC 25.629-1B Aeroelastic Stability Substantiation of Transport Category Airplanes.

J.1.1.10 AC 25.1309-1A, System Design and Analysis.

J.1.1.11 AC 25.1329-1C, Approval of Flight Guidance Systems.

J.1.1.12 AC 25.1523-1, Minimum Flightcrew.

J.1.1.13 AC 27-1B, Certification of Normal Category Rotorcraft.

J.1.1.14 AC 29-2C, Certification of Transport Category Rotorcraft.

J.1.1.15 AC 90-106A, Enhanced Flight Vision Systems

J.1.1.16 AC 120-29A, Criteria for Approval of Category I and Category II Weather Minima for Approach.

J.1.1.17 AC 120-57A, Surface Movement Guidance and Control System.

J.1.1.18 AC 120-76C, Guidelines for the Certification, Airworthiness, and Operational Use of Electronic Flight Bags.

J.1.1.19 FAA HUD, Certification Working Paper PS-ANM100-2001-0085.

J.1.2 RTCA, Inc. Documents

J.1.2.1 DO-160G, Environmental Conditions and Test Procedures for Airborne Equipment.

J.1.2.2 DO-178C, Software Considerations in Airborne Systems and Equipment Certification.

J.1.2.3 DO-200A, Standards for Processing Aeronautical Data.

J.1.2.4 DO-254, Design Assurance Guidance for Airborne Electronic Hardware.

J.1.2.5 DO-276B, User Requirements for Terrain and Obstacle Data.

J.1.2.6 DO-309, Minimum Operational Performance Standards (MOPS) for Helicopter Terrain Awareness and Warning System (HTAWS) Airborne Equipment.

J.1.2.7 DO-315A, Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems, and Enhanced Flight Vision Systems.

J.1.3 SAE International Documents.

J.1.3.1 ARP 4101, Flight Deck Layout and Facilities.

J.1.3.2 ARP 4102, Flight Deck Panels, Controls and Displays.

J.1.3.3 ARP 4103A, Flight Deck Lighting for Commercial Transport Aircraft.

J.1.3.4 ARP 4105C, Abbreviations, Acronyms, and Terms for Use on the Flight Deck.

J.1.3.5 ARP 4754A, Guidelines for Development of Civil Aircraft and Systems

J.1.3.6 ARP 4761, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

J.1.3.7 ARP 5288, Transport Category Airplane Head Up Display (HUD) Systems.

J.1.3.8 ARP 5589, Human Engineering Considerations for Design and Implementation of Perspective Flight Guidance Displays.

J.1.3.9 ARP 5677, Human Engineering Considerations for Airborne Implementation of Enhanced Synthetic Vision Systems

J.1.3.10 AS 8034, Minimum Performance Standard for Airborne Multipurpose Electronic Displays.

J.1.3.11 AS 8055A, Minimum Performance Standard for Airborne Head Up Display (HUD).

J.2 How to Get Publications.

J.2.1 Order copies of 14 CFR, from the Superintendent of Documents, Government Printing Office, P.O. 979050, St. Louis, MO 63197-9000. For general information, telephone (866) 512-1800 or fax (202) 512-2104. You can order copies online at www.access.gpo.gov. Select "U.S. Government Publishing Office Bookstore." In the search bar at the top of the page, type in "14CFR".

J.2.2 You can get copies of FAA ACs from the FAA website at www.airweb.faa.gov or www.faa.gov/reugulations_policies/advisory_circulars/.

J.2.3 You can find a current list of TSOs on the FAA Internet website Regulatory and Guidance Library at www.airweb.faa.gov/rgl. You will also find the TSO Index of Articles at the same site.

J.2.4 Order copies of RTCA documents from RTCA, Inc., 1150 18th St., NW, Suite 910, Washington, DC 20036, telephone (202) 833-9339, fax (202) 833-9434, or website: www.rtca.org

J.2.5 Order copies of SAE documents from SAE World Headquarters, 400 Commonwealth Drive, Warrendale, PA 15096-0001, USA, telephone: (877) 606-7323, or website: http://www.sae.org.

J.2.6 Order copies of military documents from the DLA Document Services, Building 4/Section D, 700 Robbins Avenue, Philadelphia, PA 19111-5098. Telephone (215) 697-2179,. You can also order copies online at http:// http://quicksearch.dla.mil/.

APPENDIX K. ADVISORY CIRCULAR FEEDBACK INFORMATION

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by (1) complete the form online at https://ksn2.faa.gov/avs/dfs/Pages/Home.aspx or (2) emailing this form to 9-AWA-AVS-AIR-DMO@faa.gov

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Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph _______ on page _______.

☐ Recommend paragraph _______ on page _______ be changed as follows:

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☐ Other comments:

☐ I would like to discuss the above. Please contact me.

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