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

Advisory Circular

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

Date: 09/08/2025

Initiated by: AIR-626B

AC No: 20-167B

This advisory circular (AC) provides guidance for gaining airworthiness approval for enhanced vision systems in aircraft. Specifically, it provides one acceptable means for complying with title 14, Code of Federal Regulations (14 CFR) part 23, 25, 27, or 29 airworthiness regulations when installing an enhanced vision system (EVS), an enhanced flight vision system (EFVS) or combined vision system (CVS) in an aircraft. This guidance was developed primarily for part 25 aircraft. You may also use this guidance for part 23, 27, and 29 aircraft. As vision system technology advances, applicants are encouraged to propose alternative methods to their AIR certification branch to integrate new and novel safety enhancing vision system functions into their aircraft.

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

DANIEL J. ELGAS

Digitally signed by DANIEL J. ELGAS
Date: 2025.09.08 11:33:13 -04'00'

Daniel J. Elgas
Aviation Safety
Director, Policy and Standards Division, Aircraft Certification Service

TABLE OF CONTENTS

Paragraph *Page*

CHAPTER 1. INTRODUCTION 1-1
1.1 Purpose 1-1
1.2 Applicability. 1-1
1.3 Cancellation. 1-2
1.4 Related Material. 1-2
1.5 Definition of Key Terms. 1-2
1.6 Background. 1-2

CHAPTER 2. VISION SYSTEMS OVERVIEW 2-1
2.1 Enhanced Vision Systems (EVS). 2-1
2.2 Enhanced Flight Vision Systems (EFVS). 2-3
2.3 Combined Vision Systems (CVS). 2-6

CHAPTER 3. AIRWORTHINESS PACKAGE CONTENTS 3-1
3.1 Airworthiness Package. 3-1
3.2 Intended Function. 3-1
3.3 Certification of a pre- 14 CFR 91.176 EFVS as an EFVS Landing System. 3-2

CHAPTER 4. SYSTEM CRITERIA 4-1
4.1 EVS (or CVS when EVS and SVS combined) – General Criteria. 4-1
4.2 EVS Specific Criteria. 4-5
4.3 CVS Specific Criteria. 4-7
4.4 EFVS – General and Specific Criteria. 4-8

CHAPTER 5. SYSTEMS INSTALLATION CONSIDERATIONS 5-1
5.1 EVS/EFVS/CVS Installations Considerations. 5-1
5.2 Continued Airworthiness and Maintenance. 5-2
5.3 EFVS Environmental Specifications. 5-2
5.4 HIRF Considerations for All Installations (EVS, CVS, and EFVS). 5-2
5.5 Software and Hardware Design Assurance. 5-3
5.6 EVS/EFVS/CVS System Safety Design Criteria. 5-3
5.7 EVS/EFVS/CVS Required Safety Level. 5-3

CHAPTER 6. PERFORMANCE EVALUATION 6-1
6.1 EVS/EFVS Performance Demonstration. 6-1
6.2 Performance Demonstration of EFVS Landing System. 6-2

APPENDIX A. FAA EFVS 14 CFR COMPLIANCE (PARTIAL LIST) A-1

APPENDIX B. SAMPLE EFVS FLIGHT TEST CONSIDERATIONS B-1

APPENDIX C. DETERMINING QUANTIFIED VISUAL ADVANTAGE C-1

APPENDIX D. SAMPLE AIRPLANE FLIGHT MANUAL (AFM) SUPPLEMENT D-1

TABLE OF CONTENTS

Paragraph *Page*

APPENDIX E. INSTALLATION OF ENHANCED VISION SYSTEM ON ROTORCRAFT E-1

APPENDIX F. DEFINITIONS AND ACRONYMS F-1

APPENDIX G. RELATED MATERIAL G-1

FIGURES

Number *Page*

Figure 2-1. Enhanced Vision Diagram 2-2

Figure 4-1. Minimum Detection Range 4-12

Figure B- 1. Depiction of Visual Advantage B-2

TABLES

Number *Page*

Table 1-1. Title 14 CFR 91.176 EFVS Visibility and Visual Reference Requirements. 4-11

Table 2-1. System Operating Phases for Considerations 5-4

Table A-1. EFVS Acceptable Methods of Compliance A-1

Table B.1. EFVS Flight Test Evaluation Matrix B-10

Table B.2. EFVS Landing System Supplemental Flight Test Evaluation Matrix B-12

CHAPTER 1. INTRODUCTION

1.1 Purpose.

In this advisory circular (AC), the Federal Aviation Administration (FAA) provides guidance on airworthiness approvals of enhanced vision system (EVS), combined vision system (CVS), and enhanced flight vision system (EFVS) equipment installation. The guidance is performance based and not limited to a specific sensor technology. This action will accommodate future growth in sensor technologies used in vision systems. This guidance was developed primarily for title 14, Code of Federal Regulations (14 CFR) part 25 aircraft. You may also use this guidance for 14 CFR part 23, 27, and 29 aircraft.

Note: As vision system technology advances, applicants are encouraged to propose alternative methods to their AIR certification branch to integrate new and novel safety enhancing vision system functions into their aircraft.

1.1.1 Existing ACs address flight guidance symbology, head-up displays (HUD) and visual display characteristics (for example, AC 25-11B, *Electronic Flight Displays*, AC 25.1329-1C, *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 appendices A and G of this AC. This AC complements existing guidance.

1.2 Applicability.

1.2.1 The guidance provided in this AC is for airplane manufacturers, modifiers, foreign regulatory authorities, Federal Aviation Administration (FAA) transport airplane type certification engineers, and FAA designees.

1.2.2 This is a guidance document. Its content is not legally binding in its own right and will not be relied upon by the Department as a separate basis for affirmative enforcement action or other administrative penalty. Conformity with the guidance document is voluntary only. Nonconformity will not affect rights and obligations under existing statutes and regulations.

1.2.3 The FAA will consider other means of demonstrating compliance that an applicant may elect to present. Terms such as "should," "may," and "must" are used only in the sense of ensuring the applicability of this particular method of compliance when the acceptable method of compliance in this document is used. If the FAA becomes aware of circumstances in which following this AC would not comply with the applicable regulations, the FAA may require additional substantiation or design changes as a basis for finding compliance.

1.2.4 The material contained in this AC does not change or create any additional regulatory requirement, nor does it authorize changes in, or permit deviations from, existing regulatory requirements.

1.3 Cancellation.

This AC cancels AC 20-167A, *Airworthiness Approval of Enhanced Vision System, Synthetic Vision System, Combined Vision System, and Enhanced Flight Vision System Equipment*, dated December 6, 2016.

1.4 Related Material.

1.4.1 This AC provides methods, procedures, and practices acceptable to the FAA for complying with applicable certification regulations. EFVS compliance references are listed in appendix A. The latest version of each AC referenced in this document is available on the FAA website at FAA Advisory Circulars and on the Dynamic Regulatory System.

1.4.2 The preamble accompanying the final rule, *Revisions to Operational Requirements for the Use of Enhanced Flight Vision Systems (EFVS)* and to *Pilot Compartment View Requirements for Vision Systems* (81 FR 90126; December 13, 2016) specifically references paragraphs 4.5.3.4, 4.5.3.4.8.4, and 6.2.6.4 of AC 20-167A. These referenced sections equate to sections 4.4.3, 4.4.3.1.8.4, and 6.2.5.4 of this AC, respectively.

1.4.3 Certain material within this AC is based upon 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 G.

1.5 Definition of Key Terms.

See appendix F for terms and definitions that apply to this AC.

1.6 Background.

This AC is for aircraft manufacturers, modifiers, and type certification engineers seeking certification or installation guidance for visual display systems. Sections 23.2600(a), 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.

1.6.1 The revision of AC 20-167A is part of a restructuring of all installation guidance for EVS, EFVS, CVS and synthetic vision systems (SVS). AC 20-167B contains all installation guidance material for EVS, EFVS, and CVS. All installation guidance regarding SVS, synthetic vision guidance systems, and aircraft state awareness synthetic vision systems has been consolidated into AC 20-185A, *Airworthiness Approval of Synthetic Vision Systems, Synthetic Vision Guidance Systems, and Aircraft State Awareness Synthetic Vision Systems*.

Note: SVS are electronic systems used to display a computer-generated image of the applicable external topography from the perspective of the flightdeck that is derived from aircraft attitude, altitude, position, and a coordinate-referenced database. Since this AC addresses EVS, EFVS, and CVS, installation guidance material for SVS that previously existed in AC 20-167A has been relocated into AC 20-185A.

CHAPTER 2. VISION SYSTEMS OVERVIEW

2.1 Enhanced Vision Systems (EVS).

2.1.1 An EVS is an electronic means to provide a display of the forward external scene topography using imaging sensors including forward looking infrared, millimeter wave (MMW) radiometry, MMW radar, and low-light-level image intensifying. EVS does not necessarily provide the additional flight information/symbology on a head-up display (HUD) or equivalent display that is required for EFVS operations under 14 CFR 91.176. While EVS share a similarity with EFVS technology, an EVS does not have to be integrated with a flight guidance system. An EVS may provide additional awareness about the external scene to the pilot, but without the additional capabilities provided by an EFVS, it is not eligible to conduct EFVS operations under § 91.176 (a) or (b).

2.1.2 The elements of an installed EVS are listed below, with the EVS diagram shown in Figure 1:

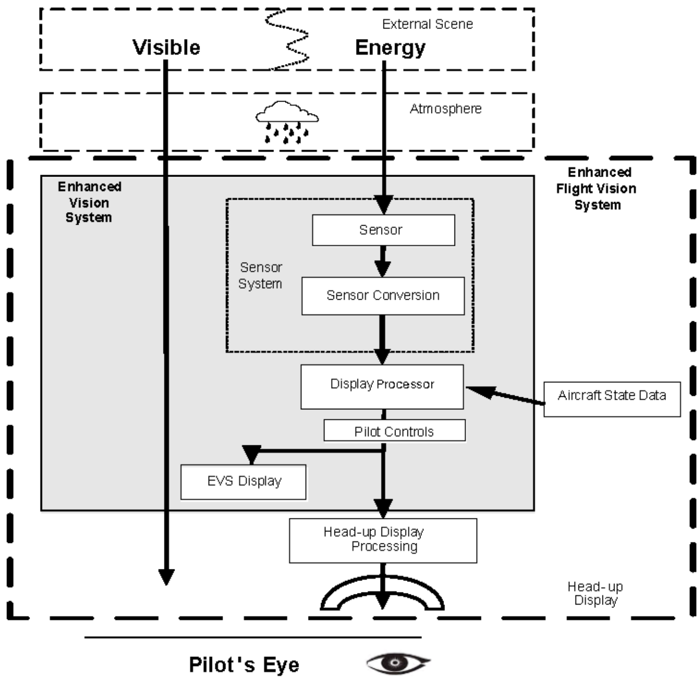
- EVS sensor system,
- Display processor,
- EVS display,
- Pilot controls/interface, and
- Mounting.

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 a HUD also applies to displays equivalent to a HUD.

Note 3: A head-worn display (HWD) could potentially meet the requirement for a HUD-equivalent display. The FAA does not currently have any published installation criteria specifically addressing HWDs. Applicants should propose a means of compliance that demonstrates that the proposed HWD is equivalent to a HUD.

Figure 2-1. Enhanced Vision Diagram



Note: Dashed lines and shading represent individual system boundaries for EVS and EFVS.

2.1.3 EVS sensors are currently categorized as passive or active sensors.

2.1.3.1 **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, while not detectable by the naked eye, will be detected depending on the capabilities of an imaging infrared system. 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 environmental conditions, they can also appear different to a pilot in the infrared image than they would with normal vision.

2.1.3.2 **Active Sensors.**

Scene contrast detected by active systems depends on several parameters: 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.

2.1.4 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 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.

2.1.5 Unlike with EFVS, an aircraft with EVS does not necessarily provide the additional flight information or symbology required by § 91.176. Unlike an EFVS, an EVS may be displayed on a head down display or on a HUD or equivalent display. The EVS display 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 a display of the external scene topography to the pilot but does not meet the regulatory requirements of § 91.176. An EVS cannot be used as a means to enhance flight visibility or to identify the required visual references in order to gain operational credit and descend below the decision altitude/decision height (DA/DH) or minimum descent altitude (MDA).

2.2 Enhanced Flight Vision Systems (EFVS).

2.2.1 An EFVS is defined in 14 CFR 1.1 as “an installed aircraft system which uses an electronic means to provide a display of the forward external scene topography (the natural or engineered 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.

2.2.2 Under § 91.176(a)(1) and § 91.176(b)(1), 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 their 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 EFVS monitor display criteria, see sections 4.4.2 and B.10 of this AC.

2.2.3 An EFVS is intended to be used to conduct an operation in which the enhanced vision image is used in lieu of natural vision to perform an approach or landing, determine the enhanced flight visibility, identify required visual references, or conduct a rollout. An EFVS requires a real-time imaging sensor that provides enhanced visibility in low visibility conditions and a level of safety suitable for the proposed operational procedure.

2.2.4 An EFVS with airworthiness approval will be designated as an EFVS approach system or EFVS landing system as described below. Under § 91.176, airworthiness approval being sought by the applicant may require additional basic equipage. Acceptable criteria for EFVS approach systems and EFVS landing systems are discussed in section 4.4 of this AC. EFVS approach systems and EFVS landing systems are briefly described in the following sections:

2.2.4.1 **EFVS Approach System**.

The installed EFVS has been demonstrated to meet an acceptable criteria, such as the criteria described in this AC, for an EFVS approach system to be used to conduct EFVS operations under § 91.176(b). The system design relies on sufficient visibility conditions to mitigate a loss of EFVS function in order to enable unaided flare and rollout. Operational guidance for use of an EFVS is published in AC 90-106B, *Enhanced Flight Vision Systems.*

2.2.4.2 **EFVS Landing System.**

The installed EFVS has been demonstrated to meet an acceptable criteria, such as the criteria described in this AC, for an EFVS landing system to be used for EFVS operations conducted under § 91.176(a). The system design relies on sufficient visibility conditions to mitigate loss of EFVS function in order to enable unaided flare and rollout. An EFVS that meets the certification criteria for an EFVS landing system also meets the certification criteria for an EFVS approach system. Operational guidance for the use of an EFVS is published in AC 90-106B.

2.2.5 Under § 91.176(a)(1) and § 91.176(b)(1), the basic elements of an installed EFVS are listed below. Guidance on specific system criteria that may be acceptable for an EFVS can be found in Chapter 4 of this AC.

2.2.5.1 The EFVS must have an electronic means to provide a display of the forward external scene topography (the applicable natural or engineered 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.

2.2.5.2 The EFVS must present 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 their 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, 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 a flare prompt or flare guidance when conducting § 91.176(a) operations.

2.2.5.3 The display should meet the following criteria:

2.2.5.3.1 The EFVS must present the displayed EFVS sensor imagery, attitude symbology, flight path vector, flight path angle reference cue (FPARC), command guidance as appropriate 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.

Note: The European Union Aviation Safety Agency (EASA) imposes additional symbology requirements that are not required by the FAA for certification or for operational approvals. Applicants that will be seeking EASA approval should consult the latest EASA guidance material to ensure compliance with EASA regulations.

2.2.5.3.2 The EFVS must display the 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.

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

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

2.2.5.3.5 The EFVS must provide display characteristics, dynamics, and cues suitable for manual control of the aircraft.

2.2.5.3.6 Installations designed to be eligible for EFVS landing system operations must also present a flare prompt or flare guidance and present height above ground level (such as that provided by a radio altimeter or equivalent device). Refer to section 4.4 of this AC for guidance on acceptable performance criteria.

2.2.6 <u>Enhanced flight vision systems.</u>

Enhanced flight vision systems display both symbology and imagery.

2.2.6.1 Symbology luminates a small fraction of the total display area of the HUD, leaving much of that area free of symbology and imagery that could interfere with the pilot's view out the window through the display.

2.2.6.2 The EVS image is in the center of the pilot's regulated “pilot compartment view.” In accordance with §§ 23.2600, 25.773(a), 27.773(a), and 29.773(a), the pilot compartment view must be clear, undistorted, and free of glare and reflection that could interfere with the normal duties of the minimum flightcrew. A video image can be more difficult for the pilot to see through than symbols 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. The outside scene must be visible, both through and around the display when the EVS image is displayed.

2.2.7 Unlike the pilot's external view, the enhanced flight vision image is historically a monochrome, two-dimensional display. Some, but not all 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.

2.2.8 For the primary display, the regulations also make provision for an equivalent display. Section 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 their normal position with the line of vision looking forward along the flight path.” To meet part 91 operational requirements, an equivalent display must be some type of head-up presentation of the required information. A head-down display does not meet the operational regulatory requirement. For guidance on monitoring display criteria, see section 4.4.2 of this AC.

2.3 **Combined Vision Systems (CVS).**

2.3.1 The CVS concept involves a combination of SVS and either 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 CVS applicants are expected to meet applicable performance criteria for each incorporated system. EVS and EFVS related guidance is located in this document. SVS related guidance can be found in AC 20-185A.

CHAPTER 3. AIRWORTHINESS PACKAGE CONTENTS

3.1 Airworthiness Package.

For the purpose of this AC, the applicant should include the following items in the airworthiness package it submits for approval.

- Intended function for the proposed system (See section 3.2 of this AC.)
- General operation for the proposed system (See chapter 4 of this AC.)
- Performance criteria and evaluation plan for the proposed system (See chapter 6 of this AC, and sample test considerations in the appendices.).
- Installation considerations for the proposed system (See chapter 5 of this AC.)

3.2 Intended Function.

3.2.1 EVS or CVS.

Define the intended functions of the EVS or CVS. Include what features will be displayed and the criticality of pilot decision-making using the display features under §§ 23.2500, 23.2505, 25.1301, 27.1301, and 29.1301, define additional intended functions (for example, terrain alerting), as appropriate to the aircraft type. It is not acceptable to identify the function of an EVS or CVS display as providing situational awareness only. If the intended function of the CVS is to be used for operational credit, then the CVS must also meet the requirements of an EFVS.

3.2.2 EFVS.

Clearly define the intended function of the EFVS (EFVS approach system or EFVS landing system), including whether its use to assess enhanced flight visibility meets or exceeds the required flight visibility of the instrument approach being flown and to visually acquire the visual references required to operate below the DA/DH or MDA as specified in § 91.176(a) and (b). The purpose of an EFVS is to enable flight in the visual segment of an approach when natural flight visibility is not adequate to meet the flight visibility requirements of the instrument approach being flown. In accordance with the operational requirements in § 91.176, an EFVS must demonstrate its ability to provide sufficient enhanced flight visibility and to clearly identify the required visual references at DA/DH or MDA necessary to conduct an EFVS operation.

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

Note 2: The purpose of an EFVS is to enhance flight visibility for the pilot in a majority of cases/weather and ambient lighting conditions.

Note 3: Past test data obtained by the applicant for an approved EFVS which demonstrated compliance may be considered for inclusion in this airworthiness package if shown to be relevant to the new application using existing practices for establishing similarity of equipment installations from one aircraft to another. For example, if the certification project intends to certify a previously approved EFVS approach system as an EFVS landing system, the applicant will need to collect new data to demonstrate the unique aspects of the EFVS landing system and may re-use data collected for the approved EFVS approach system to demonstrate aspects common to both EFVS approach systems and EFVS landing systems. In order to re-use previously collected data the applicant will need to show that the previously collected data is still applicable to the current certification application.

Note 4: Where appropriate, use of technical standard order (TSO) criteria and performance standards can be beneficial to the FAA and the applicant.

3.3 Certification of a pre- 14 CFR 91.176 EFVS as an EFVS Landing System.

On December 13, 2016, the FAA published Amendment 91-345 (81 FR 90172) to update then existing §§ 91.175(l) and (m), the prior regulation addressing EFVS use during the segment of an approach that extended from DA/DH or MDA down to 100 feet above the touchdown zone elevation (TDZE). The updated rule expanded the use of EFVS to landings under specified conditions. Section 91.176 was added to cover EFVS use during both landing and approach. Section 91.176(a) addresses EFVS use during landing. The rules for approach that were previously contained in § 91.175(l) and (m) were re-designated as § 91.176(b). EFVS systems that were eligible for operation under §§ 91.175(l) and 91.175(m) are now eligible for § 91.176(b) operations as EFVS approach systems. Systems approved prior to the effective date of § 91.176 (March 13, 2017) must meet the updated applicable airworthiness standards from the rule to be eligible for § 91.176(a) operations as EFVS landing systems. The EFVS landing system application should include the following:

- How the EFVS meets all the requirements of § 91.176(a)(1).
- How the EFVS meets the applicable airworthiness standards for EFVS landing systems as described in AC 20-167B.

Note: Past test data obtained by the applicant for an approved EFVS which demonstrated compliance may be considered for inclusion in this airworthiness package if shown to be relevant to the new application using existing practices for establishing similarity of equipment installations from one aircraft to another.

CHAPTER 4. SYSTEM CRITERIA

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

Unless otherwise specified, the EVS/CVS mandatory criteria in this chapter are in accordance with §§ 23.2600(a), 25.773, 27.773 and 29.773. Applicants showing compliance to § 23.2600 should use the criteria found in § 23.773(c), Amendment 23-63, or ASTM F3117M-24a (or later as stated in the FAA's part 23.), or propose their own means of compliance.

4.1.1 EVS/CVS Primary Displays.

EVS or CVS functionality can be superimposed on the electronic flight instrument system, such as the primary flight display (PFD) as installed in the flightdeck. In this configuration example, the EVS 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 HUD equivalent display system using EVS or CVS capabilities. Maneuvering the aircraft during any phase of flight (taxi, approach, landing, rollout, etc.) should not be predicated on EVS or CVS imagery alone.

4.1.2 EVS/CVS Secondary Displays.

EVS or CVS functionality can be displayed on secondary electronic displays or display windows but is not used for PFD applications. Examples of secondary displays include multi-function displays (MFD), navigation displays, and exocentric displays.

4.1.2.1 The secondary vision system image or loss thereof should not adversely affect other approved secondary display functionality (e.g., navigation display).

4.1.2.2 The secondary display should be such that it cannot be confused with, considered as, or used as a PFD.

4.1.2.3 If primary flight information is presented on a secondary display, the information should be of sufficient quality that it does not cause someone to doubt the PFD data.

4.1.3 Intended Function.

Under §§ 23.2500, 23.2505, 25.1301, 27.1301, and 29.1301, the intended function of any installation of EVS/CVS must be clearly defined as appropriate to the aircraft in which the system is being installed. The design and installation safety levels must be appropriate for the stated intended function. Although normally associated with use during flight, utilization of an EVS display during ground operations should not be used if sensor proximity to the taxiway surface causes a distraction.

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

4.1.3.2 Operating limitations should be proposed to the FAA by the applicant. In accordance with §§ 23.2620, 25.1581, 27.1581, and 29.1581, operating limitations must be clearly defined and stated in the aircraft's flight manual supplement in line with the intended function.

4.1.3.3 An EVS that does not meet the requirements in § 91.176 for EFVS operations cannot be used in lieu of natural vision to descend below DA/DH or MDA, regardless of whether it is on a HUD or on a head down display.

4.1.4 <u>Guidelines for EVS/CVS.</u>

The proposed system (EVS/CVS):

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

4.1.4.2 Must not degrade presentation of essential flight information. 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/CVS image.

4.1.4.3 Must 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 if the vision system uses a head-up display or equivalent display. Refer to Society of Automotive Engineers (SAE) design standards for distortion prescribed in SAE Aerospace Standard (AS) 8055A. See section 4.1.5.2 of this chapter for additional HUD or equivalent display criteria.

4.1.4.4 Must not adversely affect any other installed aircraft system. See §§ 23.2500, 23.2505, 25.1301, 27.1301, and 29.1301 for function and installation. See §§ 23.2510, 25.1431, and 29.1431 for electrical equipment.

4.1.4.5 Must perform its intended function in each aircraft environment where system approval is desired. See §§ 23.2500, 23.2505, 25.1301, 27.1301, and 29.1301. For example, if the system is intended to perform in (or after exposure to) known icing conditions, provide a means to keep the EVS sensor window clear of ice accumulation.

4.1.4.6 Should display the mode of operation (EVS, or CVS) to the pilot/flightcrew. Consideration should be given to recording the EVS/CVS display status in a flight data recorder or some form of nonvolatile memory. The modes of the EFVS operation should be made available to the flight data recorder, in addition to all the information required by §§ 23.1459, 25.1459, 27.1459, and 29.1459 or by an operational rule that the applicant seeks to show compliance to during certification (e.g. 14 CFR 121.344).

4.1.4.7 Should not have undesirable display characteristics (for example, jitter, jerky motion, and excessive delays.) Refer to SAE design standards for jitter prescribed in SAE AS 8055A.

4.1.5 Display Implementation.

EVS/CVS can be incorporated into different display types installed in the flightdeck. 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.

4.1.5.1 **Primary Flight Display (PFD).**

Primary flight displays are flightdeck displays used to provide information needed to guide and control the aircraft and provide the aircraft altitude, attitude, and airspeed indications. EVS/CVS can be implemented on the primary head down display (HDD) in part 23 and 25 aircraft. Refer to AC 27-1B CHG 1-9, *Certification of Normal Category Rotorcraft,* and AC 29-2C CHG 9, *Certification of Transport Category Rotorcraft*, for guidance on installation on rotorcraft. The following criteria apply to EVS/CVS implemented on a PFD:

4.1.5.1.1 The image, or loss thereof, should not adversely affect the PFD functionality.

4.1.5.1.2 Alignment of imagery presented on the PFD should be consistent with the real world, appropriate for the system's intended function accounting for possible aircraft attitudes, turbulence, and wind effects, and not mislead the flightcrew. If two displays show EVS or CVS information, or a combination (EVS on one and CVS on another), the orientation of the displays should be the same.

4.1.5.1.3 All spatially referenced symbology must be scaled and aligned within each axis with the imagery so as not to present any misleading information to the pilot.

4.1.5.1.4 The field of regard (FOR) can be variable. However, in accordance with §§ 23.2600, 25.771, 27.771, and 29.771 and §§ 23.2500, 23.2505, 25.1309, 27.1309, and 29.1309, the FOR must be designed to ensure the displayed image is not distracting or misleading and does not adversely affect flightcrew performance and workload.

4.1.5.1.5 The display should not impede a clearly visible zero pitch reference line. The zero pitch reference line should be 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.

4.1.5.1.6 Under §§ 23.2600, 25.771, 27.771, and 29.771 and §§ 23.2600(a), 25.773, 27.773, and 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.

4.1.5.2 **Head-Up Display or Equivalent Display.**

4.1.5.2.1 A design with EVS/CVS imagery displayed on a HUD must account for the pilot compartment view, including validation that the display of EVS imagery does not conflict with the pilot compartment view.

4.1.5.2.2 The following tasks associated with the use of the pilot's view should 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; and
- Accurate identification and utilization of visual references required for every task relevant to the phase of flight.

Note: Utilization of video imagery on the HUD or HUD equivalent display during ground operations should not be considered if sensor proximity to the taxiway surface causes distracting imagery.

4.1.5.2.3 Imagery on the HUD or HUD 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.

4.1.5.2.4 Specific design standards for resolution and line width, luminance and contrast ratio, chromaticity, and grayscale should be applied. Refer to SAE international design standards for HUD symbology, optical elements and video imagery, which are prescribed in SAE AS 8055A, *Minimum Performance Standard for Airborne Head Up Display (HUD)*, dated July 2015. Recommended best practices can be found in: 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.

Note: The intellectual property in each of these documents is owned by SAE, (not the FAA), and is subject to change. In general, SAE has a 5-year review cycle for each of their documents.

4.1.5.3 Secondary displays. EVS/CVS can be implemented with egocentric "inside aircraft" views or exocentric "outside aircraft" viewpoints on head down displays. This includes installed electronic flight bags (EFBs) or MFDs. The following criteria apply to EVS/CVS implemented on secondary displays:

4.1.5.3.1 EVS/CVS image, or loss thereof, must not adversely affect other approved display functionality (such as navigation displays). See §§ 23.2500, 23.2505, 25.1301, 27.1301, and 29.1301.

4.1.5.3.2 The secondary display should be such that it cannot be confused with, considered as, or used as a PFD.

4.1.5.3.3 If primary flight information is presented on a secondary display, it should be of sufficient quality that it does not cause someone to doubt the PFD data.

4.1.5.3.4 The orientation and perspective of the EVS/CVS view should be clear to the pilot. Generally, the orientation of the secondary display should be the same as the orientation of 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 The following are specific criteria for EVS installations:

4.2.2.1 The EVS depiction must be flightcrew de-selectable (if on the primary display, the pilot must be able to easily and quickly remove the sensor image.) For an EVS image displayed on a HUD or HUD 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 their hands from the primary flight and power controls, or their equivalent. See §§ 23.2500, 23.2505, and 25.1301, 27.1301, 29.1301, and §§ 23.2600(a), 25.773, 27.773 and 29.773.

4.2.2.2 The display mode (status of EVS), either through flightcrew de-selection or as a result of a failure, should be clearly indicated or obvious to the flightcrew. See §§ 23.2500, 23.2505, and 25.1301, 27.1301, 29.1301, and §§ 23.2600(a), 25.773, 27.773 and 29.773.

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

4.2.2.4 Specific design standards for resolution and line width, luminance and contrast ratio, chromaticity, and grayscale should be applied. Refer to SAE design standards for EVS symbology, optical elements and video imagery are also prescribed in SAE AS 8055A, SAE ARP 5288, and SAE ARP 5287.

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 airplanes certificated under part 25, all display characteristics listed in AC 25-11B should be applied. For airplanes certificated under part 23, all display characteristics listed in AC 23.1311-1C should be applied. For rotorcraft certificated under part 27 or 29, all display characteristics listed in AC 27-1B CHG 1-9 or AC 29-2C CHG 9 (respectively), should be applied. 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, fixed pattern noise and running water). Refer to SAE design standards for display characteristics prescribed in SAE AS 8055A.

4.2.2.6 Consider the following criteria for image characteristics for the EVS design:

4.2.2.6.1 On an 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 HUD equivalent display. Minification up to a ratio of 3:1 has been shown to be acceptable.

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

Note: Refresh rates above 50 Hz for cathode ray tube (CRT) based HUDs may be required to prevent unacceptable levels of flicker. Refer to SAE AS 8055A.

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: An EVS display refresh rate 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.

4.2.2.7 For display on a HUD or HUD equivalent display, the system should provide a control of the EVS display contrast/brightness which is effective in dynamically changing background (ambient) lighting. The minimum system should 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 an EVS is incorporated on the primary flight display, the EVS-based primary display should 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 the use of chevrons or pointers on all attitude indications to perform effective manual recovery from unusual attitudes. (For airplanes certificated under part 25, refer to AC 25-11B).

4.3 CVS Specific Criteria.

4.3.1 CVS requires a real-time imaging sensor and display that provides demonstrated vision performance for its intended function. It also requires 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:

4.3.1.1 CVS should meet the respective criteria of the EVS and SVS implementations. Installation guidance for SVS displays can be found in AC 20-185A.

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

4.3.1.3 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 flightcrew. Significant image discrepancies between EVS and SVS due to failure conditions should be obvious to the flightcrew.

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.

4.3.2 The CVS should meet the detailed performance criteria for EVS specified in sections 4.2 and 4.3 of this chapter and SVS performance criteria listed in AC 20-185A.

4.4 EFVS – General and Specific Criteria.

4.4.1 If the intended function of the EFVS is to meet § 91.176, the EVS criteria above as well as the following EFVS general and specific criteria, are applicable to the EFVS:

4.4.1.1 Under §§ 23.2500, 23.2505, 25.1309, 27.1309, and 29.1309, the design assurance level of the aircraft systems must be commensurate with the identified failure probabilities.

4.4.1.2 The sensor image, combined with the required aircraft state and position reference symbology, must be presented to the flightcrew on the HUD, or an equivalent display, so that they are clearly visible to the pilot flying in their normal position and line of vision looking forward along the flight path. For HUD or HUD 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. See SAE AS8055A criteria on conformality.

4.4.1.3 The HUD or HUD equivalent display and displayed FOR must 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 must be presented in the form of symbology overlaying the image presentation. Section 91.176(a)(1)(B) requires the following flight instrument data on the HUD, or HUD equivalent display:

- 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.

Note: EASA has additional symbology requirements that are not required by the FAA for EFVS certification or for operational approvals. Applicants that will be seeking EASA approvals should consult the latest EASA guidance material to ensure compliance with EASA regulations.

4.4.1.4 In addition to criteria in 4.4.1.3, the following specified aircraft flight information required for operation by § 91.176(a)(1)(i)(B) must also be displayed for an EFVS landing system:

- Height above ground level such as that provided by a radio altimeter or other device capable of providing equivalent performance; or
- For aircraft other than rotorcraft, flare prompt or flare guidance for achieving acceptable touchdown performance, as discussed in section 6.2.

4.4.1.5 **Flare Cue.**

Under § 91.176(a)(1)(i)(B), an EFVS landing system for aircraft other than rotorcraft 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 that it meets the landing criteria found in section 6.2. For some aircraft, flare guidance may be necessary because a flare prompt is not sufficient.

4.4.1.6 **Flare Prompt.**

The flare prompt indicates to the pilot when to initiate the flare but does not provide direction/guidance on how to execute the flare maneuver. The flare prompt should be presented at an appropriate time and with sufficient saliency so that the flare maneuver will be neither too early nor too late and within the touchdown zone as described in section 6.2 of this AC. The appearance and dynamic behavior of the flare prompt should be distinguishable from command guidance.

4.4.1.7 **Flare Guidance.**

Flare guidance provides explicit command guidance to the pilot for when to initiate the flare and provides directional cues on how to execute the flare maneuver. The flare guidance directs the flare maneuver so that the flare would be neither too early nor too late, and within the touchdown zone as described in section 6.2 of this AC.

4.4.1.8 The minimum system should include a control of EFVS display contrast/brightness, for manually controlled EFVS systems, and should include a control for automatic EFVS systems that 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, and prevents other negative impacts on 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.

4.4.1.9 Under §§ 23.2600(a), 25.773(e)(3), 27.773(c)(3), and § 29.773(c)(3), the EFVS display controls must be visible to and within reach of the pilot flying, from any normal seated position with the seat belt and shoulder harness (if applicable) fastened. If each pilot station is equipped with EFVS, the EFVS display controls must be visible to, and within reach of each pilot from any normal seated position. The position and movement of the controls must not lead to an inadvertent operation. The EFVS controls, except those located on the pilot's flight controls, must be adequately illuminated for all normal background lighting conditions, and must not create any objectionable reflections on the HUD or HUD 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 their hands from the primary flight and power controls, or their equivalent.

4.4.1.10 The approach path situation references and command guidance should be based on the specific navigation source for the straight-in instrument approach procedure in use.

4.4.1.11 Under § 91.176, upon reaching the DA/DH or minimum descent altitude (MDA), 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 (See appendix C, "Determining Quantified Visual Advantage"). The visual references of the runway environment must be seen by the sensor at or beyond the distance required in the visual segment of the instrument approach being flown.

Table 1-1. Title 14 CFR 91.176 EFVS Visibility and Visual Reference Requirements.

From the authorized DA/DH to 100 feet height above TDZE 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.

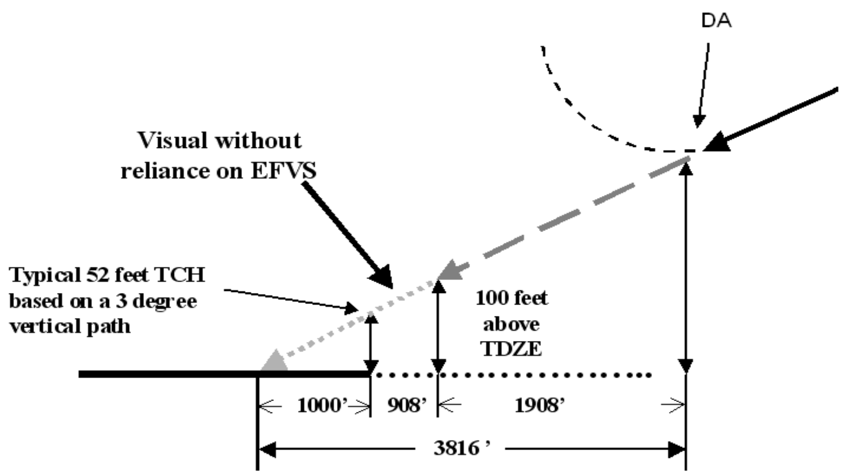
1. Under § 91.176, the pilot must identify the runway threshold using at least one of the following visual references:
    a. The beginning of the runway landing surface; or
    b. The threshold lights; or
    c. The runway end identifier lights.
2. Under § 91.176, the pilot must identify the touchdown zone using at least one of the following visual references:
    d. The runway touchdown zone landing surface; or
    e. The touchdown zone lights; or
    f. The touchdown zone markings; or
    g. 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 following features must be identified without reliance on the EFVS approach system. For EFVS landing and rollout operations the following listed features may be identified using an EFVS landing system:

1. The runway threshold; or
2. The lights or markings of the threshold; or
3. The runway touchdown zone landing surface; or
4. The lights or markings of the touchdown zone.

4.4.1.12 The minimum detection EFVS range (figure 4-1) can be derived by using an assumed minimum distance of the aircraft at the nominal Category I (200 ft.) DA/DH before which the EFVS should image the runway threshold. On a 3 degree glideslope, the horizontal distance from the aircraft to the runway threshold is approximately 2,816 feet (3,816 feet from the precision aim point markings). In all cases, in accordance with § 91.176(a)(3), the EFVS must provide sufficient enhanced visibility at the DA/DH or MDA equal to the prescribed visibility of the instrument approach being conducted. These values do not take into account pilot decision time or actual atmospheric conditions. However, the use of non-precision approaches can require greater distances, or initiating approaches with higher DAs, DHs, or MDAs.

Figure 4-1. Minimum Detection Range



4.4.1.13 Under §§ 23.2600(a), 25.773, 27.773, and 29.773, the EFVS imagery displayed on the HUD or HUD equivalent display must account for the pilot compartment view requirements, 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, and a means to deactivate the display that 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; and

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

Note: Utilization of video imagery on the HUD or HUD equivalent display during ground operations should not be considered if sensor proximity to the taxiway surface causes distracting imagery.

4.4.2 EFVS Display Criteria.

Unless otherwise specified, §§ 23.2600(a), 25.773, 27.773 and 29.773 serve as the regulatory bases for the EFVS mandatory display criteria in this section.

4.4.2.1 For EFVS implemented on a HUD, the image should be compatible with the field of view (FOV) and head motion box of a HUD designed against SAE ARP 5288 (transport category head-up display (HUD) systems), or an equivalent standard. 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, in accordance with § 91.176(a)(1)(ii) 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 a display that provides the pilot monitoring with EFVS sensor imagery. Under §§ 23.2500, 25.1321, 27.1321, and 29.1321, all displays used to monitor the approach must be located in the flightdeck so that either pilot seated at the controls can monitor the airplane's flight path and instruments with minimum head and eye movement. Any symbology displayed should not adversely obscure the sensor imagery of the runway environment.

4.4.2.2 Under 14 CFR parts 21, 23, 25, 27, and 29, the EFVS display must meet applicable airworthiness certification requirements (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.

4.4.2.3 Current FAA guidelines for HUDs apply with respect to EFVS. These criteria include well-established military and civil aviation standards for HUDs as defined in MIL-STD-1787D, *Aircraft Display Symbology*, and AC 25-11B. Specific design standards for image size, resolution and line width, luminance and contrast ratio, chromaticity, and grayscale should be applied. SAE design standards for HUD symbology, optical elements, and video imagery are also prescribed within SAE AS 8055. Recommended practices are included in SAE ARP 5288 and SAE ARP 5287.

4.4.2.4 The EFVS installation and the EFVS image, when superimposed on the HUD symbology must:

4.4.2.4.1 Under § § 23.1301 25.1301, 27.1301 29.1301 and 23.1309, 25.1309, 27.1309 and 29.1309, be suitable for and successfully perform its intended function.

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

4.4.2.4.3 Under § § 23.1301 25.1301, 27.1301 29.1301 and 23.1309, 25.1309, 27.1309 and 29.1309, have acceptable display characteristics to accomplish the intended function.

4.4.2.4.4 Have a means to allow the pilot using the display to immediately deactivate and reactivate the vision system imagery on demand, without removing their hands from the primary flight and power controls, or their equivalent.

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

4.4.2.4.6 Under § § 23.2600, 25.771(a), 27.771(a), 29.771(a) and 25.1302(b), not be misleading, cause confusion, or significantly increase pilot workload.

4.4.2.4.7 Be aligned with and scaled to the external scene.

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

4.4.2.4.9 Under § § 23.2600, 25.771(a), 27.771(a), 29.771(a) and 25.1302(b), not alter external scene colors in a way that causes confusion, significantly increases workload and/or prevents the pilot from performing any required tasks (e.g., discerning precision approach path indicators).

4.4.2.4.10 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.

4.4.2.5 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.

4.4.2.6 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. The use of chevrons, pointers, and/or permanent ground-sky horizon on all attitude indications to perform effective manual recovery from unusual attitudes has been shown to be an acceptable means to aid in recovery from unusual attitudes. Refer to AC 23.1311-1C, AC 25-11B, AC 27-1B CHG 1-9 and AC 29-2C CHG 9 for guidance on electronic flightdeck displays.

4.4.2.7 Under § 91.176 the EFVS must display a flight path vector (FPV) and flight path angle reference cue (FPARC) on the HUD or HUD equivalent display. The following criteria apply to these symbols:

4.4.2.7.1 The position and motion of the FPV should correspond to the aircraft's earth-referenced flight path vector. The display should provide for a FPV depiction when at the limit of the FOR.

4.4.2.7.2 The dynamic response of the FPV should not exhibit undue lag or overshoot due to pilot control inputs. If flight path vector quickening is used, adequate testing should demonstrate that the quickening employed actually improves performance and does not introduce any undesirable dynamics to the display. Refer to AC 25-11B, paragraphs A.7 and F.5.4.5;

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

4.4.2.7.4 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.

4.4.2.8 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.

4.4.2.9 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.

4.4.3 EFVS Detailed System Criteria.

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.

4.4.3.1 **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.

4.4.3.1.1 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. At best, EFVS latency causes 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.

4.4.3.1.2 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 FOR should be 5 degrees (± 2.5 degrees) vertical and 20 degrees horizontal.

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.
2. The EFVS image should be compatible with the field-of-view and head motion box of a HUD designed against SAE ARP 5288, or equivalent standard. The HUD and EFVS FOR should provide a conformal image with the visual scene over the range of aircraft attitudes and wind conditions for each mode of operation. Limitations should be clearly specified in the aircraft flight manual (AFM) if the HUD cannot be used throughout the full aircraft flight envelope.
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 degrees about the flight path vector to allow for momentary flight path perturbations and to allow sufficient fore/aft view of the required visual references.

4.4.3.1.3 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 and creating the potential for misleading or distracting imagery.

4.4.3.1.4 Jitter.

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

4.4.3.1.5 Flicker.

Flicker is brightness variations at a frequency above 0.25 Hz per SAE ARP 5288. The minimum standard for flicker should meet the criteria of SAE ARP 5288, or equivalent. Flicker can cause mild fatigue and reduced flightcrew efficiency. In accordance with §§ 23.2600(a), 25.773, 27.773 and 29.773, the EFVS and HUD cannot exhibit flicker greater than that of the HUD itself.

4.4.3.1.6 Image artifacts.

The EFVS must not exhibit any objectionable noise, local disturbances, or an artifact that prevents the system from meeting its intended function. The EFVS design should minimize display characteristics or artifacts (for example, internal system noise, fixed pattern noise, 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. See §§ 23.2600(a), 25.773, 27.773 and 29.773.

4.4.3.1.7 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). Under SAE ARP 5288, the total HUD system display accuracy error, as measured from the HUD eye reference point, should be less than 5 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, or an equivalent standard. 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 boresight error allowed for the EFVS sensor, since it is assumed any error can be electronically compensated during installation. With EFVS operations, the aircraft is essentially flown irrespective of the EFVS/HUD dynamic error, to the MDA or DA/DH. 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.

4.4.3.1.8 Sensor/sensor processor.

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.

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 in order to comply with §§ 23.2600(a), 25.773, 27.773 and 29.773. 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.

3. **Sensor resolution.**

As a minimum, EFVS resolution performance must adequately resolve (for pilot identification) the runway threshold and the touchdown zone to enable the intended function. See §§ 23.2500, 23.2505, and 25.1301, 27.1301, and 29.1301. For example, an EFVS should resolve a 60 ft wide runway from 200 ft above touchdown zone elevation with a typical 3-degree glideslope. The sensor resolution was established by providing this resolution at a minimum range, allowing the pilot to continue the descent below DA/DH or MDA. (These values do not take into account pilot decision time or actual atmospheric conditions, or the use of non-precision approaches that may require greater distances.) A 60 ft.-wide runway was chosen as the International Civil Aviation Organization (ICAO) minimum runway width to support an instrument approach procedure.

4. **Passive sensor optical distortion.**

Optical distortion should be 5 percent or less across the minimal FOR as defined in section 4.4.3.1.2 and no greater than 8 percent outside the minimal FOR.

5. Sensor sensitivity.

In this context, the EFVS sensor sensitivity should be at least a noise equivalent temperature difference (NETD) of 50 degrees 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 glideslope 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.

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 flightcrew. See §§ 23.2500, 23.2505, 25.1309, 27.1309, 29.1309 and AC 25-11B, appendix F.

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 specified in Table 1. Blooming to the extent the required visual references are no longer distinctly visible and identifiable is unacceptable.

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 meet the provisions of section 4.4.3.1.6 by a secondary on-demand process (for example, the NUC process).

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 the algorithms will eventually degrade the image quality and accuracy due to the sheer number and closely-spaced location of the elements.

10. Parallax.

The effects of parallax caused by lateral, vertical, and longitudinal offset of the sensor from the pilots’ design eye points must not impede the EFVS from performing its intended function, as evaluated during flight test. See §§ 23.2500, 23.2505, 25.1301, 27.1301, and 29.1301. Parallax should not degrade landing performance parameters (e.g., flare height, sink rate, touchdown location, and groundspeed during landing, exit and taxi) between EFVS operations and visual operations in the same aircraft.

CHAPTER 5. SYSTEMS INSTALLATION CONSIDERATIONS

5.1 EVS/EFVS/CVS Installations Considerations.

5.1.1 EVS/EFVS/CVS Pilot Controls and Annunciations.

5.1.1.1 The EVS/EFVS/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/EFVS/CVS controls, except those located on the pilot's control inceptor (e.g., control wheel, yoke, stick, etc.), should be adequately illuminated for all normal background lighting conditions and should not create any objectionable reflections on other flight instruments. See §§ 23.2600(a), 25.773, 27.773 and 29.773.

5.1.1.3 There should be a means to manually modulate illumination unless fixed illumination of the EVS/EFVS/CVS controls is shown to be satisfactory under all lighting conditions. See §§ 23.2600(a), 25.773, 27.773 and 29.773.

5.1.1.4 Any modes of EFVS operation should be annunciated on the flightdeck and visible to the flightcrew. The modes of the EFVS operation should be made available to the flight data recorder, in addition to all of the information required by §§ 23.1459, 25.1459, 27.1459, and 29.1459, or by an operational rule that the applicant seeks to show compliance to during certification (e.g. 14 CFR 121.344).

5.1.2 EFVS Fail Safe Features.

The normal operation of the EFVS should not adversely affect or be adversely affected by other normally operating aircraft systems. Under §§ 23.1309, 25.1309, 27.1309, 29.1309, the flightcrew must be alerted through annunciation (or other means of providing warning information) to any detected malfunctions of the EFVS which could cause display of misleading information, and the misleading information should be removed. Alerting annunciations should be displayed to the flightcrew in accordance with AC 23.1311-1C, AC 25.1322-1, AC 25-11B, AC 27-1B CHG 1-9 and AC 29-2C CHG 9, as applicable. Under §§ 23.2500, 23.2505, 25.1309, and 27.1309, the applicant must assess the criticality of the EFVS's function to display imagery, including the potential to display hazardously misleading information. Likewise, the assessment must include the hazardous effects of any malfunction of the EFVS that could adversely affect interfaced equipment or associated systems. See AC 23-1309-1E, AC 25-11B, and Army Reserve Aviation Command (ARAC)-recommended 25.1309 and Arsenal Guidance, AC 27-1B CHG 1-9 and AC 29-2C CHG 9. This requirement should be met through a system safety assessment (SSA) and documented via fault tree analysis (FTA), failure mode and effects analysis (FMEA), and FMEA substantiation, or equivalent safety documentation.

5.1.3 The electrical system must be able to furnish the required power at the proper voltage for the EVS/CVS. See §§ 23.2525, 25.1310, 27.1351 and 29.1351.

5.1.4 EVS/EFVS/CVS Built-In Test (BIT).

The applicant should provide a BIT capability that, at a minimum, limits the exposure time to latent failures consistent with the exposure limits in the SSA.

5.2 Continued Airworthiness and Maintenance.

5.2.1 Under § 23.1529, 25.1529, 27.1529, and 29.1529, the applicant must develop instructions for continued airworthiness for maintaining the EVS/CVS/EFVS and its components.

5.2.2 Under § 21.50, Instructions for Continued Airworthiness (ICA) must be furnished after final design approval. Refer to FAA Order 8110.54A, *Instructions for Continued Airworthiness*, for additional guidance on FAA's procedures for administering ICA requirements.

5.2.3 Other maintenance tasks may be developed as a result of the safety assessment, design reviews, manufacture's recommendations and Maintenance Steering Group 3 (MSG-3) analyses that are conducted. These instructions include but are not limited to removal and replacement, troubleshooting, cleaning, maintenance procedures for the MEL relief and software loading/configuration control.

5.3 EFVS Environmental Specifications.

Applicants should follow the guidance in AC 21-16G (as revised), and RTCA DO-160 versions D, E, F and G, *Environmental Conditions and Test Procedures for Airborne Equipment*. Additionally, under §§ 23.2520, 25.1316, 25.13l7, 27.13l7, 29.1316, or 29.1317, or related special conditions, the EFVS must also meet the high-intensity radiated fields (HIRF), electromagnetic interference, and lightning requirements as specified in the certification basis of the aircraft in which the EFVS is to be installed.

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

Under §§ 23.2520, 25.13l7, 27.13l7, or 29.1317, the immunity of critical avionics/electronics and electrical systems to HIRF must be established. Critical avionics/electronics and electrical system 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 additional guidance.

5.5 Software and Hardware Design Assurance.

5.5.1 Follow the guidance in AC 20-115D, Airborne Software Development Assurance Using EUROCAE ED-12 and RTCA DO-178 to develop software. Use the version which is current at time of application.

5.5.2 Follow the guidance in AC 20-152, RTCA, Inc., Document RTCA/DO-254, *Design Assurance Guidance for Airborne Electronic Hardware*, to develop your airborne electronic hardware, if applicable. Use the version which is current at time of application.

5.6 EVS/EFVS/CVS System Safety Design Criteria.

A complete functional hazard assessment (FHA) and SSA should be conducted to identify failure modes and classify the hazard levels. Under §§ 23.2500, 23.2505, 25.1309, 27.1309, and 29.1309, the ability of the system design to perform its intended function must be demonstrated through analysis and engineering tests to preclude failures that can cause hazardously misleading information to be presented to the pilot or the flightcrew, 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.

5.7 EVS/EFVS/CVS Required Safety Level.

Under §§ 23.2500, 23.2505, 25.1309, 27.1309, and 29.1309, the applicant must perform a safety assessment based on the proposed installation for the given aircraft and intended function for each phase of flight. The SSA should address both the loss and the incorrect display of information, including hazardously misleading information. The hazard effects of all malfunction of the EVS/EFVS/CVS that could adversely affect interfaced equipment or associated systems should be determined and assessed according to the applicable certification rules and associated advisory materials.

5.7.1 Transport Category Airplanes.

Section 25.1309 defines the safety requirement, and ARAC-recommended § 25.1309 and Arsenal Guidance provide guidance for demonstrating compliance to show verification.

5.7.2 Non-Transport Category Airplanes.

Sections 23.2500 and 23.2505 define the regulatory safety requirement, and AC 23-1309-1E provides guidance for demonstrating compliance. Severity of failure conditions and software development assurance levels are found in AC 23.1309-1E.

5.7.3 Rotorcraft.

Sections 27.1309 and 29.1309 define the safety requirements. Regulatory guidance can be found in AC 27-1B CHG 1-9 and AC 29-2C CHG 9.Once the safety assessment has been completed, for any hazard or failure classification greater than Major, an FTA should be evaluated using the guidance found in the FAA system safety AC that is applicable to the installation. The FTA should include the display monitor, power supply, imaging camera and sensors, cable, status annunciations, and other components that affect the top-level events.

5.7.4 The SSA should consider the sample operating phases in Table 2-1.

Table 2-1. 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

5.7.5 The normal operation (without malfunction) of the EVS/EFVS/CVS should not adversely affect or be adversely affected by other normally operating aircraft functions. As applicable, similar criteria are found in SAE ARP 4754 and ARP 4761A.

5.7.6 Demonstration.

Under §§ 23.2600, 25.771(a), 27.771(a), 29.771(a) and 25.1302(b), to meet the safety criteria, the EFVS design must be demonstrated to mitigate any failure combinations that can cause hazardously misleading information to be presented to the flightcrew, or which can otherwise subsequently cause an unsafe condition. Failures which are self-evident or made obvious to the flightcrew, and with which they can safely cope, need not be specifically monitored.

5.7.7 State Data.

The aircraft state data are provided by the standard inertial, air data, and radio guidance sensors. Under §§ 23.1309, 25.1309, 27.1309 and 29.1309, 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 or MDA 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.

5.7.8 EFVS system safety design criteria analysis (as applicable).

To demonstrate compliance with §§ 23.2500, 23.2505, 25.1309, 27.1309, 29.1309:

5.7.8.1 The overall level of safety of the aircraft is based on installed equipment. A complete 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 the flightcrew, 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.

5.7.8.2 The EFVS system must perform its intended function for each applicable operation and phase of flight in which it would be used.

5.7.8.3 The normal operation of the EFVS must not adversely affect or be adversely affected by other aircraft systems. The EFVS should annunciate detected malfunctions of the system and remove the malfunctioning display elements.

5.7.8.4 RTCA DO-315A, appendix C, lists sample categories of systems and failure probabilities to meet the safety criteria in transport category airplanes. The applicant should consider these samples when adapting to their specific design and the intended aircraft type (i.e., part 23, 25, 27 or 29 aircraft). 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 CHG 1-9 and AC 29-2C CHG 9, as appropriate for the installation.

5.7.8.5 The applicant should validate all alleviating flightcrew actions and any cues that provide crew awareness (e.g.: alerts, status) that are considered in the EFVS safety analysis during testing either for incorporation in the AFM/airplane flight manual supplement or rotorcraft flight manual/rotorcraft flight manual supplement (RFM/RFMS) limitation section or procedures section, or for inclusion in type-specific training.

5.7.9 <u>EFVS approach system required level of safety analysis (as applicable).</u>

To demonstrate compliance with §§ 23.2500, 23.2505, 25.1309, 27.1309, and 29.1309 should take the following items into consideration:

5.7.9.1 Safety design goals for airworthiness approval should be established when designing an EFVS approach system. 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. 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 should show the pilot can perform that intervention. For example, a pilot might be assumed to detect a system error because of other displays or what is being viewed 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.

5.7.9.2 The applicant should demonstrate a satisfactory safety (failure and performance) level which should 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 DA/DH that can be expected for an EFVS approach system based approach to 100 ft. above the TDZE.

5.7.9.3 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 flightdeck flight information system.

5.7.9.4 There are failure modes within the EFVS approach system which determine that software and hardware DALs should use the criteria of the latest versions of RTCA DO-178 (for software) and DO-254 (for hardware) level C as a minimum. Depending upon specific functions or system architecture, a higher DAL (for example see RTCA DO-315A, appendix C) may result from the DAL allocation analysis.

5.7.9.5 The safety assessment process, starting with the FHA, should determine whether the minimum required DAL C is adequate for your specific installation. The example FHA shown in RTCA DO 315A, appendix C is a model case only and cannot be applied to any specific aircraft without independent analysis.

5.7.9.6 The applicant must provide the applicable analysis that is specific for each installation approval. An example SSA of an EFVS approach system is shown in RTCA DO-315A, appendix C.

5.7.9.7 The applicant must conduct a safety analysis to show the EFVS approach system meets all the integrity criteria for the aircraft, HUD, and EFVS. The applicant should demonstrate system and subsystem malfunctions, which are not extremely improbable, as appropriate in a simulation or in flight. The malfunction annunciation and fault detection schemes must achieve the determined level of safety.

5.7.10 <u>EFVS landing system required level of safety analysis (as applicable).</u>
To demonstrate compliance with §§ 23.2500, 23.2505, 25.1309, 27.1309, and 29.1309:

5.7.10.1 The applicant should 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.

5.7.10.2 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.

5.7.10.3 An aircraft level FHA and 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 DALs 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 B.

5.7.10.4 The minimum required safety level for an EFVS landing system (EFVS to touchdown and roll out in visibilities not less than runway visual range (RVR) 1000 feet) is based on the assumption that the EFVS being approved can demonstrate that the flightcrew can verify that the aircraft is safely approaching the runway for EFVS landing system based landing, or if not, to initiate a timely go-around if sufficient enhanced visibility is not achieved. This provides additional integrity to the operation. Depending on the applicant's design, it may be possible that the proposed natural 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 capability remains of the EFVS landing system. A safe landing should not be assumed with only available natural vision after total loss of the EFVS landing system (i.e., symbology and image).

5.7.10.5 In showing compliance with these safety criteria, the applicant should not factor probabilities of EFVS landing system failure conditions by the fraction of approaches which require use of the EFVS landing system. Also, the applicant should 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.

5.7.11 SSA analysis (as applicable).

To demonstrate compliance with §§ 23.2500, 23.2505, 25.1309, 27.1309, and 29.1309 analysis should contain the following elements:

5.7.11.1 An aircraft-level 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 DALs are appropriate to the applicant's specific intended function.

5.7.11.2 The DALs are directly linked to the specific intended use and to the specific EFVS installation as an integrated part of the flightdeck 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 the operation should be considered when assessing the appropriate hazard levels for the EFVS.

5.7.11.3 Under §§ 23.2500, 23.2505, 25.1309, 27.1309, and 29.1309, the applicant must provide an SSA.

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

5.7.11.5 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) as determined by the AIR certification branch and the project specific certification plan (PSCP).

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

5.7.11.7 All aircraft configurations to be approved must be addressed.

5.7.12 EFVS Fail Safe Features.

Under 23.2500, 25.1353(a), 27.1351(b), and 29.1353(a), the normal operation of the EFVS must not adversely affect or be adversely affected by other normally operating aircraft systems. Warning information (e.g. annunciations) must be provided to alert the crew to unsafe EFVS operating conditions, including detected malfunctions of the EFVS which could cause display of misleading information. The misleading information should be removed. Alerting annunciations should be displayed to the flightcrew in accordance with AC 23.1311-1C, AC 25.1322-1, AC 25-11B, AC 27-1B CHG 1-9, and AC 29-2C CHG 9 as applicable. Under §§ 23.2500, 23.2505, 25.1309, 27.1309, and 29.1309, the applicant must assess the criticality of the EFVS's function to display imagery, including the potential to display hazardously misleading information. That assessment should include the hazardous effects of any malfunction of the EFVS that could adversely affect interfaced equipment or associated systems. See AC 23-1309-1E, AC 25-11B, and ARAC-recommended 25.1309 and Arsenal Guidance, AC

27-1B CHG 1-9 and AC 29-2C CHG 9. This requirement should be met through an SSA and documented via FTA, FMEA, and FMEA substantiation, or equivalent safety documentation.

CHAPTER 6. PERFORMANCE EVALUATION

6.1 EVS/EFVS Performance Demonstration.

The performance demonstration used to establish aircraft system compliance with applicable FAA airworthiness criteria typically includes bench testing, simulation, flight testing, data collection, and data reduction to show that the proposed performance criteria can be met. The performance evaluations should therefore include demonstrations of the kinds of operations and those operations' flight regimes that are stated as the system's intended functions. 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 is sought. Appendix B of this AC provides sample EFVS flight test considerations.

6.1.1 This AC does not prescribe specific test procedures. We recognize that alternative methods can be used. In accordance with §§ 21.17 and 21.97, your test procedures and compliance reports must show compliance with the applicable airworthiness criteria. System performance tests are the most important tests, as they relate to operational capability. Subsystem tests are used to test subsystems during system buildup to ensure appropriate subsystem performance as it relates to overall system performance.

6.1.2 The applicant should use some or all these four general verification methods as necessary (Refer to AC 23.1309-1E, AC 25.1329-1C, AC 27-1B or AC 29-2C CHG 9 as applicable).

6.1.2.1 **Analysis.**

Demonstrate compliance using an engineering analysis.

6.1.2.2 **Flight Test.**

Demonstrate compliance using an aircraft that is fully representative for the purpose of the test in terms of flightdeck geometry, instrumentation, alerts, indications, and controls in the air and on the ground.

6.1.2.3 **Laboratory Test.**

Demonstrate compliance using an engineering bench representative of the final EVS/CVS/EFVS system being approved.

6.1.2.4 **Simulation.**

Demonstrate compliance using a flight simulator as accepted by the AIR certification branch in the PSCP.

6.1.3 The applicant should specify the individual verification methods used in the certification plan. Confirm that the responsible AIR certification branch agrees with your plan before you begin. For extensions, features, and design decisions not explicitly specified in this AC, you should conduct human factors evaluations. Conduct these evaluations through appropriate combinations of analyses, bench testing, simulation, or flight testing.

6.1.4 The applicant should verify both the installed system and the individual system components meet the EVS/CVS/EFVS criteria described in Chapter 4 of this AC.

6.1.5 The applicant should demonstrate the system meets performance criteria specified in Chapter 4 by flight test and/or other appropriate means, which can include the use of a flight simulator. An example of a flight test program for EFVS is described in appendix C 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 addressed in this AC.

6.1.6 The applicant should conduct an evaluation of the system used during anticipated operational scenarios, including:

6.1.6.1 EFVS Flight Testing.

Unapproved EFVS systems may be operated on test flights provided that the operation is conducted under § 91.176(d) and the aircraft is issued an experimental certificate under § 21.191.

6.1.6.2 Section 21.191, Experimental Certificates.

Identifies a number of purposes for which an experimental certificate can be issued. Not all of those are eligible for the exception in § 91.176(d). Section 91.176(d) limits the exception purposes to only those listed in §§ 21.191(a) and 21.191(b). Please note, however, that using an unapproved EFVS to conduct an EFVS operation outside this specific scope would still require a waiver from the applicable operating rules.

For the Administrator to determine that the flight test operations can be conducted safely in accordance with § 91.176(d) and all other applicable regulations, the FAA will evaluate the flight test in accordance with FAA Order 8130.2J, *Airworthiness Certification of Aircraft*. FAA Order 8130.2J contains detailed instructions about how to obtain an experimental certificate (Chapter 4, Sec. 2 and Chapter 10.) It also describes what the applicant’s program letter must contain (appendix C) and lists what operating limitations must be applied to the experimental certificate (appendix D). As a part of the airworthiness certification process, the FAA determines whether the operations proposed by the applicant can be safely conducted. The FAA issues operating limitations when the program letter is approved, and the experimental certificate is issued.

6.2 Performance Demonstration of EFVS Landing System.

Where appropriate for the performance demonstration, the non-visual conditions can be achieved either by natural obscuration or by the 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.

6.2.1 Under §§ 23.2610, 25.1523, 27.1523, and 29.1523, the applicant must consider the workload associated with the use of EFVS landing system for approach, landing and rollout.

6.2.2 The system may fly final approach courses with offsets greater than 3 degrees. In this case, the applicant should establish the maximum allowable final approach course offset by flight test. The flight test should address factors related to the offset, such as HUD/EFVS FOV, crosswinds, and the maximum drift angle for a conformal FPV.

6.2.3 The EFVS landing system image with superimposed flight symbology must not mislead, distract or jeopardize the safety of the landing and rollout. Performance should be demonstrated to be no worse than that normally achieved in visual operations for the specific aircraft for all performance parameters measured. See §§ 23.2600, 25.771, 27.771, 29.771 and §§ 23.2500, 23.2505, 25.1309, 27.1309, and 29.1309. The applicant may propose a valid means for establishing performance normally achieved that the FAA may accept as a benchmark for the EFVS demonstrations.

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

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

6.2.5.1 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.

6.2.5.2 A smooth transition through flare to landing.

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

6.2.5.4 Touchdown within the touchdown zone. The lateral touchdown performance should be demonstrated to be no worse than that achieved in visual landings for the specific aircraft.

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

6.2.5.6 Touchdowns with a bank angle that is not hazardous to the aircraft. Demonstrated performance of the installed EFVS at representative visibilities for EFVS approach system and EFVS landing system operations as described in this AC will determine any additional limitation (for example, crosswind and offset).

6.2.5.7 A normal de-rotation.

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

6.2.5.9 A safe go-around anytime including up to touchdown in all aircraft approach/landing configurations to be certified.

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

A.1 Airworthiness Standards.

- Certification Procedures for Products and Articles (14 CFR part 21).
- Normal Category Airplanes (14 CFR part 23).
- Transport Category Airplanes (14 CFR part 25).
- Normal Category Rotorcraft (14 CFR part 27).
- Transport Category Rotorcraft (14 CFR part 29).

A.2 EFVS Compliance.

The following requirements address EFVS compliance. These requirements may also be in addition to those requirements applicable to a HUD and the basic avionics installation. The amount of new test data can be determined by the individual application, availability, and relevance of data.

Table A-1. EFVS Acceptable Methods of Compliance

14 CFR	Description	Acceptable Method of Compliance
23.2135, 25.143, 27.143, 29.143	General controllability and maneuverability	Analysis, Simulation, Flight Test
23.2160, 25.251, 27.251, 29.251	Vibration and buffeting	Flight Test
23.2210, 23.2230, 25.301, 27.301, 29.301	Loads	Analysis
23.2230, 25.303, 27.303, 29.303	Factor of safety	Analysis
23.2235, 25.307, 27.307, 29.307	Proof of structure	Analysis

14 CFR	Description	Acceptable Method of Compliance
25.561m 25.562(c)(5)	Emergency landing conditions; Head Injury Criterion (HIC)	Analysis
23.2240, 25.571, 27.571, 29.571	Damage-tolerance and fatigue evaluation of structure	Analysis
25.571(e)	Damage-tolerance and fatigue evaluation of structure(discrete source) evaluation	Analysis and/or Test (See Note)
23.2515, 25.581, 27.610, 29.610	Lightning protection	Analysis
23.2250, 25.601, 27.601, 29.601	General Design and Construction	Drawing
23.2250, 23.2260, 25.603, 27.603, 29.603	Materials	Drawing
23.2260, 25.605, 27.605, 29.605	Fabrication methods	Drawing
23.2255, 25.609, 27.609, 29.609	Protection of structure	Drawing
23.2255, 25.611, 27.611, 29.611	Accessibility provisions	Drawing
23.2260, 25.613, 27.613, 29.613	Material Strength properties and material design values	Drawing, Analysis, Test (See Note)
23.2265, 25.619, 27.619, 29.619	Special factors	Analysis
23.2265, 25.625, 27.625, 29.625	Fitting Factors	Analysis
23.2245, 25.629(d)(8)	Aeroelastic stability	Analysis, Test

14 CFR	Description	Acceptable Method of Compliance
23.2320(d), 25.631, 29.631	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.)
23.2600, 25.771, 27.771, 29.771	Pilot compartment	Flight Test
23.2600(a), 25.773, 27.773, 29.773	Pilot compartment view	Flight Test
23.2600, 23.2610, 25.777, 27.777, 29.777	Flight deck controls	Flight Test
23.2500, 23.2505, 25.1301, 27.1301, 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
23.2500, 23.2505, 25.1309, 27.1309, 29.1309	Equipment, systems, and installations	Analysis and/or Test and Design data
25.1316, 27.1316, 29.1316	System lightning protection	Analysis and Ground Test
23.2520, 25.1317, 27.1317, 29.1317	High-intensity Radiated Fields (HIRF) Protection	Ground Test and Flight Test Analysis/Data
23.2500, 23.2610, 25.1321, 27.1321, 29.1321	Arrangement and visibility	Ground Test and Flight Test
23.2605, 25.1322, 27.1322, 29.1322	Warning, caution, advisory lights	Ground Test and Flight Test
25.1323, 27.1323, 29.1323	Airspeed indicating systems	Flight Test

14 CFR	Description	Acceptable Method of Compliance
23.2500 23.2505, 23.2510, 23.2600, 23.2605, 27.1335, 29.1335	Flight director systems	Ground Test and Flight Test
23.2525, 23.2500, 23.2525, 23.2605, 25.1351, 27.1351, 29.1351	Electrical Systems and Equipment; General	Analysis
25.1353, 29.1353	Electrical equipment and installation	Analysis
23.2500, 23.2505, 23.2510, 23.2525, 25.1357, 27.1357, 29.1357	Circuit protective devices	Analysis and Ground Test
23.2500, 23.2600, 25.1381, 27.1381, 29.1381	Instrument lights	Ground Test and Flight Test
23.2165(a)(1), 23.2540(a), 23.2600(a), 25.1419, 27.1419, 29.1419	Ice protection	Analysis
23.2510, 25.1431, 29.1431	Electronic equipment	Analysis and Ground Test
23.1549(e), 25.1459(e), 27.1459(e), 29.1459(e)	Flight data recorders	Flight test
23.2610, 25.1501, 27.1501, 29.1501	Operating Limitations and Information; General	Flight Test
23.2610, 25.1523, 27.1523, 29.1523	Minimum flightcrew	Flight Test or Simulation
23.2610, 25.1525, 27.1525, 29.1525	Kinds of operation	Flight Test
23.1529, 25.1529, 27.1529, 29.1529	Instructions for Continued Airworthiness	Design Data

14 CFR	Description	Acceptable Method of Compliance
23.2620, 25.1581, 27.1581, 29.1581	Aircraft flight manual; General	Design Data and Flight Test
23.2620, 25.1583, 27.1583, 29.1583	Operating limitations	Flight Test Data
23.2620, 25.1585, 27.1585, 29.1585	Operating procedures	Flight Test Data
26.47	Holders of and applicants for a supplemental type certificate - alterations and repairs to alterations.	Analysis

APPENDIX B. SAMPLE EFVS FLIGHT TEST CONSIDERATIONS

B.1 General Flight Test Considerations.

The objectives of the flight test program are to demonstrate the installed EFVS performs its intended function when installed, and to document that the installed EFVS is eligible for operational approval.

B.1.1 Testing should include all phases of flight, approach types, approach course geometries, and aircraft configurations for which the applicant seeks to operate the EFVS. The EFVS minimum performance standards require the assessment of the EFVS display when used in conjunction with the head up flight indications required in § 91.176 and listed in paragraph 4.4.1.3 of this AC. For effective post-flight analysis and evaluation of the results, past experience has shown that recorded time-stamped video of exactly what is displayed on the HUD is recommended.

B.1.2 In general, the test program should demonstrate that the EFVS image, with superimposed flight symbology, does not mislead, distract or jeopardize the safety of the approach, 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 the EFVS approach or EFVS landing as described in § 91.176. Minimum performance standards require the assessment of the HUD/EFVS approach system display when used in conjunction with the flight instrumentation required in § 91.176 and listed in paragraph 4.4.1.3 of this AC.

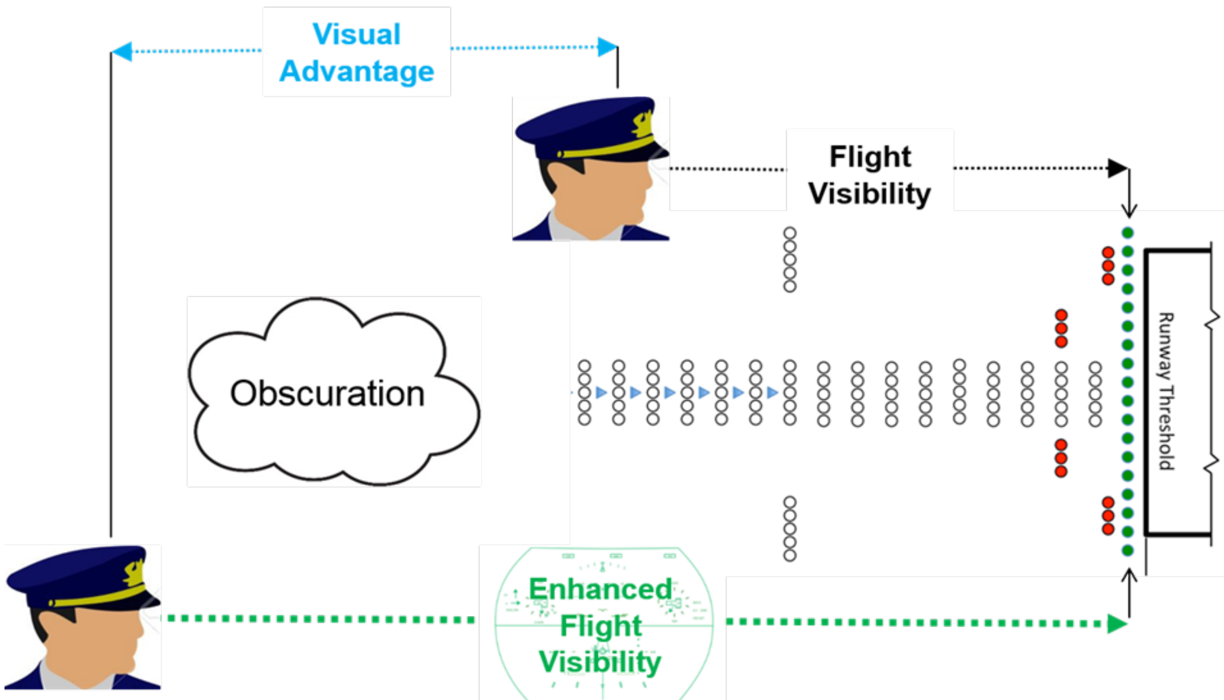
B.1.3 The flight test should demonstrate that the EFVS display of imagery and HUD symbology are readable and usable without mutual interference. Flight testing should demonstrate the brightness and contrast levels of the imagery and the symbology can be effectively controlled and provide satisfactory contrast between the two. Since flightdeck and external light levels can affect the readability of the EFVS display and can change significantly throughout the approach and landing operation, flight testing should demonstrate that control of display brightness and contrast in dynamic conditions does not require excessive workload for the pilot. Additionally, flight tests should demonstrate that controls can clear the EFVS imagery from the HUD in the event that the visual field becomes unusable due to system malfunction or external environmental conditions.

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

B.1.5 An applicant may reuse previously collected certification flight test data to meet the criteria specified in this AC if the applicant can show the previously collected certification data is relevant to the current certification project. The FAA and the applicant will agree on the reuse of any previously collected certification flight test data. For example, if an applicant is certifying a previously certified EFVS approach system as an EFVS landing system, and the applicant can show test data collected to certify the

EFVS approach system meets the criteria specified in this AC, the applicant may only need to conduct the additional EFVS landing system specific test points listed in this appendix.

Figure B- 1. Depiction of Visual Advantage



B.2 **Evaluation of Visual Advantage.**

In addition to demonstrating system safety, the flight test program should demonstrate that the installed EFVS is capable of successfully completing the relevant § 91.176(a) or 91.176(b) operation in a representative sampling of weather and environmental conditions with flight visibilities lower than the published instrument approach visibility minimums as described in section B.3 of this AC.

B.2.1 A successful demonstration of visual advantage in accordance with appendix B is sufficient to support certification of the installed EFVS. However, while not required for certification of the EFVS, quantification of the demonstrated EFVS visual advantage is required for some EFVS operational approvals.

B.2.2 The demonstration of a quantified visual advantage is necessary to authorize the provisions in OpSpec/MSpec/Letter of Authorization (LOA) C048 which allow 14 CFR part 121, 125, and 135 certificate holders to use EFVS-equipped aircraft to:

B.2.2.1 Release a flight under instrument flight rules (IFR) when the forecast weather is equal to or greater than the authorized minimums for use with an EFVS. (§§ 121.613, 125.361, and 135.219); and

B.2.2.2 Continue an approach when the weather is reported to be equal to or greater than authorized minimums for use with an EFVS. (§§ 121.651, 125.325, 125.381, and 135.225.)

B.2.3 If the applicant intends the system to be used for EFVS operations that require OpSpec/MSpec/LOA C048, it is recommended that the applicant also demonstrate and document the EFVS's quantified visual advantage during the certification testing of the EFVS. Further guidance on how to quantify the visual advantage of the EFVS is found in appendix C.

B.3 Minimum Flight Test Conditions Observed.

Testing should demonstrate fault-free approaches for EFVS approach systems or approach and landings for EFVS landing systems in as many of the conditions listed below as practicable and as applicable to the system's intended function. Additionally, a sufficient number of approaches will be needed in a representative sampling of weather and environmental conditions with flight visibilities lower than the published instrument approach visibility minimums to demonstrate that the EFVS can provide sufficient enhanced flight visibility to complete the EFVS operation. Past experience has shown that the applicants with a new EFVS should plan for no less than 50 fault-free approaches for EFVS approach systems or approach and landings for EFVS landing systems. Include go-around performance in testing. Typically, at least five satisfactory go-arounds are included in testing.

B.3.1 The applicant and the FAA will agree on the minimum number of successfully demonstrated test approaches.

B.3.2 Testing of the EFVS systems should be conducted in as many of the environmental conditions listed below as practical and applicable to the system's intended function. The environmental conditions should be chosen to exercise both the automatic and manual control of items such as brightness, contrast, gain, and any other parameter that affects the image displayed to the pilot. The actual environmental conditions used for the flight test program must be agreed to by the FAA. Address the conditions in the following subsection when developing the flight test program:

B.3.2.1 EFVS approach and EFVS landing systems should be tested under the following conditions:

- Night visual flight rules (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 to include airports with LED lighting where relevant to the systems intended function;
- Representative airport/runway surface conditions (dry, wet, standing water, snow cover);
- Representative thermal crossover conditions as applicable for the EVS sensor;
- 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.); and
- Representative instrument approaches for the intended EFVS operations.

B.3.2.2 **Additional conditions for EFVS landing systems.**

- Representative runway widths usable to aircraft on which the EFVS is being installed; and
- Representative runway slopes (within the aircraft limitations).

B.3.3 Data Collection.

The applicant should propose a method to collect and analyze system performance in order to demonstrate that the installed EFVS meets all relevant criteria. The data collection method found in RTCA DO-390/EUROCAE ED-291, *Test Procedures for Quantitative Visual Advantage,* is recommended for use on all EFVS flight tests in support of appendix B. Collecting data in a manner consistent with RTCA DO-390/ED-291 could support future certification or operational approval applications and mitigate the need to fly additional test flights.

B.3.4 Faulted Approaches.

A faulted approach occurs anytime the pilot is unable to complete a safe and successful approach, landing, or rollout and turnoff. Examples of faulted approaches are included below. The list provides examples. Each unique system design could generate additional faulted approach cases.

B.3.4.1 **Examples of a faulted approach:**

- 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 flightdeck is within and tracking so as to remain within the lateral confines of the extended runway;
- Due to a confusing or misaligned image, the touchdown will be too short or too long; and/or
- The EFVS approach system image degrades the flyability of the display such that a successful approach to DA/DH or MDA is not possible.

B.3.4.2 A faulted approach does not occur due to a lack or loss of enhanced flight visibility due to the atmospheric conditions, so long as a successful missed approach or rejected landing is executed.

B.3.4.3 A faulted approach also does not occur due to air traffic control intervention, interference from other aircraft, interference from ground vehicles or persons, interference from animals (e.g. birds), or any other reason not directly related to the EFVS.

B.4 **Taxi Evaluation Steps.**

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

B.4.2 Verify that the EFVS display, 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 task.

B.4.3 Verify that 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 task.

B.4.4 Assess any burn-in or blooming (if applicable) on the EFVS image from high intensity heat sources such as operating engines, stationary lights etc.

B.5 **Take off Evaluation Steps.**

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

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

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

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

B.5.5 Evaluate the EFVS image during the take-off roll and throughout the climb segment, against the attributes listed in the flight test evaluation matrix. See Table B-1 and Table B-2.

B.6 Climb and Descent and Lateral Modes Evaluation Steps.

B.6.1 Evaluate climb, descent, and lateral modes in day and night instrument meteorological conditions and visual meteorological conditions to assess HUD/EFVS compatibility.

B.6.2 During vertical and lateral guidance maneuvers, evaluate the EFVS image against the attributes listed in the flight test evaluation matrix. See Table B-1 and Table B-2.

B.7 Instrument Approaches.

B.7.1 During any instrument approach for which approval is sought, EFVS compatibility should be evaluated against the attributes listed in the flight test evaluation matrix. See Table B-1 and Table B-2.

B.7.2 Speed control should be demonstrated to be maintained 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.

B.7.3 EFVS landing systems may fly final approach courses with offsets greater than 3 degrees. In this case, establish the maximum allowable final approach course offset by flight test. The flight test should address factors related to the offset, such as HUD/EFVS field of view, crosswinds, and the maximum drift angle for a conformal FPV. Section 91.176 permits EFVS to touchdown for approaches with offsets up to 15 degrees. The flight test evaluation should factor this offset into potential limitations and airworthiness approvals.

B.7.4 The EFVS must present all display requirements of § 91.176(a)(1) or § 91.176(b)(1) throughout the entire instrument approach. If any of the required EFVS display elements are not shown during an approach type that the aircraft is approved to conduct (i.e., steep approaches), then a limitation should be annotated in the AFM.

B.8 Final Approach from the DA/DH or MDA, Flare Landing, and Rollout to a Safe Taxi Speed.

B.8.1 While using EFVS during final approach and through the flare (below 50 ft), touchdown roll or go-around, and turn-off, assess the performance of the EFVS image and displayed symbology against the attributes listed in the flight test evaluation matrix. See Table B-1 and Table B-2.

B.8.2 Confirm that 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.

B.8.3 For EFVS approach systems, assess the transition to natural vision and compatibility of the guidance when following the HUD/EFVS approach system flight cues.

B.8.4 The EFVS landing system should be evaluated to ensure that the system provides:

- A smooth transition through flare to landing;
- Approach, flare, and landing at a normal sink rate for the aircraft;
- Have display characteristics, dynamics, and cues that are suitable for manual control of the aircraft to touchdown in the touchdown zone of the runway of intended landing and during rollout;
- Touchdown within the touchdown zone and that the lateral touchdown performance should be demonstrated to be no worse than that achieved in visual landings for the specific aircraft;
- Prompt and predictable correction of any lateral deviation away from the runway centerline to smoothly intercept the centerline;
- Touchdowns with a bank angle that is not hazardous to the airplane;
- 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);
- A normal de-rotation rate;
- Satisfactory and smooth control of the airplane from touchdown to a safe taxi speed; and
- Satisfactory and smooth control of the path of the airplane along the runway centerline through rollout to a safe taxi speed.

B.9 Rejected Landing.

Confirm that at any time during the EFVS operation, a rejected landing can be safely conducted in all configurations to be approved.

B.10 Pilot Monitoring (PM) Display Steps.

B.10.1 Display Location.

B.10.1.1 EFVS Approach Systems.

A PM display 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.

B.10.1.2 EFVS Landing System.

Section 91.176(a) requires a PM display. Under §§ 23.2500, 23.2610, 25.1321, 27.1321, 29.1321, verify that the display's location meets the certification requirement and any symbology displayed does not adversely obscure the sensor imagery of the runway environment.

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

B.10.3 If the display has dual purposes, verify that the means of switching the display to the EFVS approach system monitor and back is satisfactory and clearly evident.

B.10.4 Verify no unacceptable flicker and/or jitter in the display.

B.10.5 Verify that no objectionable glare or reflections are generated by the display or are visible in the display.

B.10.6 Verify that the co-pilot's use of the EFVS approach system monitor does not require undue head/body movement away from their normal scan pattern or their normal seated position.

B.10.7 If the PM display is a HUD or equivalent display, verify that 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.

B.10.8 The PM display should be shown to be acceptable for the pilot monitoring to see and identify visual references and verify that all visual requirements for the approach and/or landing are satisfied.

B.11 Failure Cases.

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

B.12 Ice Protection System Evaluation.

B.12.1 If the EFVS approach system sensor installation has ice protection capability, the EFVS image should be evaluated with the ice protection on and off in representative environmental conditions.

B.12.2 Icing of the sensor fairing/radome should be appropriately assessed in accordance with the approved flight envelope.

B.13 Flight Test Evaluation Matrix.

The flight test evaluation matrix is a table of recommended aspects of the EFVS installation that should be evaluated during the flight test program. The applicant should propose a flight test evaluation matrix that is suitable for the applicant's specific EFVS installation. As a starting point, Table B-1 contains the recommended minimum flight test evaluation matrix for all EFVS installations. Table B-2 contains the recommended minimum supplemental test evaluations specific to EFVS landing systems.

Table B-1. EFVS Flight Test Evaluation Matrix

A	Confirm flightcrew workload is not adversely affected by the EFVS installation.
B	Verify no adverse physiological effects from using the EFVS (for example, fatigue, eye strain).
C	Verify EFVS 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 unacceptable jitter or flicker of EFVS symbology/image.
E	Verify that the EFVS 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 image, assess HUD guidance and ensure that introduction of EFVS 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 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 imagery and HUD symbology does not over clutter the HUD combiner display area.
J	Assess the degree of obscuration of the pilot's outside view or field of view through the flightdeck window as a result of EFVS 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 imagery.
L	Confirm that there is no discrepancy between the conformal HUD symbols, sensor image, and the outside view through the flightcrew's windows.
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 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 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 their task performance or safety.
T	Verify that the enhanced flight visibility provided by the EFVS is greater than the instrument approach procedure minimums and required visual references are clearly identifiable with the EFVS at DA/DH or MDA.
U	Confirm that the EFVS image is suitable and performs its intended function.
V	Confirm that the sensor image on the pilot monitor 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 fight test evaluation matrix.
X	During vertical and lateral guidance maneuvers, evaluate the EFVS image against the attributes listed in the pilot evaluation matrix.
Z	Evaluate the EFVS using all available HUD modes and/or declutter options as appropriate for the phase of flight and condition.

Table B-2. EFVS Landing System Supplemental Flight Test Evaluation Matrix

A	Confirm that the EFVS provides the correct and appropriate visual cues for the pilot to perform the required stabilized approach from the DA/DH.
B	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.
C	Confirm that the EFVS provides the correct visual cues for the pilot to perform a smooth transition through flare to landing.
D	Confirm that the EFVS provides the correct visual cues for the pilot to perform a flare and landing with a normal sink rate.
E	Confirm that the EFVS provides the correct visual cues to always allow a consistent touchdown in the defined touchdown zone.
F	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.
G	Confirm that the EFVS provides the correct visual cues to allow normal derotation rate.
H	Confirm that EFVS provides the correct visual cues to allow satisfactory and smooth control of the airplane from touchdown to a safe taxi speed.
I	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.

APPENDIX C. DETERMINING QUANTIFIED VISUAL ADVANTAGE

C.1 Introduction.

Demonstrating a quantified visual advantage is not required for the installed EFVS to be approved. However, any operator that uses the installed EFVS to dispatch the aircraft in accordance with § 121.613, § 125.361, or § 135.219, or to commence an instrument approach under § 121.561, § 125.325, § 125.381, or § 135.225 requires an operational approval from the FAA's Flight Standards Service. For the operator to receive the required operational approval, the applicant must demonstrate and document a quantifiable measure of the EFVS visual advantage performance.

C.2 Quantified Visual Advantage Test Plan.

For determination of visual advantage, a data set demonstrating in-flight the relationship between slant range flight visibility and slant range enhanced flight visibility (visual advantage) with the reported visibility should be created and analyzed.

C.2.1 <u>RTCA DO-390/EUROCAE ED-291, Test Procedures for Quantitative Visual Advantage.</u>

Provides an industry consensus methodology for testing and documenting the quantitative visual advantage provided by the installed EFVS. The methodology in DO-390/ED-291 has been deemed to be acceptable to FAA Flight Standards for the purposes of documenting the performance of the installed EFVS and supporting applications for operational approvals.

C.2.2 <u>Alternate Methods.</u>

An applicant may propose alternate methods of measuring and documenting the quantified visual advantage of the system. Should the applicant propose an alternate method to test the visual advantage for the installed EFVS, it is recommended that the applicant coordinate with the FAA's Flight Standards Service to ensure that the results of the proposed quantitative visual advantage testing will be sufficient to support an operator's application for operational approvals.

APPENDIX D. SAMPLE AIRPLANE FLIGHT MANUAL (AFM) SUPPLEMENT

D.1 Introduction.

Appendix D presents a sample below for the AFM supplement for Supplemental Type Certificate (STC) installations. This example may not be entirely applicable to airplane manufacturers when EVS, CVS, or EFVS are approved with the type certificate. The AIR certification branch will assist the applicant in developing an appropriate RFMS.

Installation Center/Repair Station Model XXX EVS/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 FAA-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

APPENDIX D. SAMPLE AIRPLANE FLIGHT MANUAL (Continued)

Installation Center/Repair Station Model XXX EVS/EFVS

123 Fourth Street Vision System

Anytown, USA

Table of Contents

Section..Page

1 General..< >

2 Limitations.......................................< >

3 Emergency/Abnormal Procedures....< >

4 Normal Procedures..........................< >

5 Performance.....................................< >

6 Weight and Balance.........................< >

7 System Description..........................< >

FAA Approved Page <> of <>

Date: ________

APPENDIX D. SAMPLE AIRPLANE FLIGHT MANUAL (Continued)

Installation Center/Repair Station Model XXX EVS/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 the regulatory requirements and performance criteria as described in AC 20-167B for <*situation awareness*>.

CVS: The installed ABC Combined Vision System meets the regulatory requirements and performance criteria as described in AC 20-167B for <*situation awareness*>.

EFVS Approach System: The demonstrated visual advantage of the installed <Manufacture, Model #> EFVS landing system meets applicable requirements as described in AC 20-167B for EFVS operations to
100 feet above the touchdown zone and is eligible for operational credit in accordance with the operator's specific EFVS approvals.

Note: The <Manufacture, Model #> EFVS landing system does not provide a visual advantage when viewing LED lighting

EFVS Landing System*:* The demonstrated visual advantage of the installed <Manufacture, Model #> EFVS landing system meets applicable requirements as described AC 20-167B for EFVS operations to touchdown and roll out and is eligible for operational credit in accordance with the operator's specific EFVS approvals.

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

Note: The <Manufacture, Model #> EFVS landing system does not provide a visual advantage when viewing LED lighting.

APPENDIX D. SAMPLE AIRPLANE FLIGHT MANUAL (Continued)

SECTION 2 - LIMITATIONS

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

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

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

FAA-Approved Page <> of <>

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 is 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 global positioning system (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*>.

APPENDIX D. SAMPLE AIRPLANE FLIGHT MANUAL (Continued)

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.*>

FAA-Approved Page <> of <>

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.*>

FAA-Approved Page <> of <>

Date: ________

APPENDIX E. INSTALLATION OF ENHANCED VISION SYSTEM ON ROTORCRAFT

E.1 General.

This appendix provides guidelines for the installation of EVS installed in rotorcraft as non-required safety enhancing equipment. Policy statements PS-ASW-27, 29-10 (dated May 29, 2013), PS-AIR-21.8-1602 (dated March 31, 2016), and PS-ASW-27-15 (dated June 30, 2015) were published to promote standardized installation of non-required safety enhancing equipment. Contact the appropriate FAA office responsible for rotorcraft standards for guidance. Also refer to AC 27-1B CHG 1-9 and AC 29-2C CHG 9 for certification guidance.

E.2 Applicability.

There are unique aspects to rotorcraft that do not apply to fixed wing aircraft. Rotorcraft typically operate at altitudes much closer to obstacles and the ground 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 the pilot oriented correctly. There are advantages and disadvantages to presenting EVS 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 or CVS displays that interact with automated flight control systems and flight guidance systems.

E.3 Airworthiness Approval.

For rotorcraft, the FAA has determined that installation of EVS or CVS on a primary flight display, either ADI or NAV display, requires AIR certification branch involvement through the STC process, under FAA Order 8900.1A, 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.

E.4 **Design Considerations.**

The FHA developed for the system should define the hazards of presenting misleading information to the pilot, and the loss of an 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 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 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. However, for rotorcraft the FAA does not accept "situation awareness only" information on primary flight displays (either PFD or MFD within the pilot's primary field of view). Therefore, the intended function of the EVS/CVS should be defined. If helicopter terrain awareness and warning system (HTAWS) or HTAWS-like features are incorporated, see TSO-C194.

APPENDIX F. DEFINITIONS AND ACRONYMS

F.1 Definitions.

F.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.

F.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).

F.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.

F.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).

F.1.5 Conformal (AC 25-11B).

Refers to displayed graphic information that is aligned and scaled with the outside view.

F.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.

F.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.

F.1.8 Egocentric.

Used to define the view of a display image that correlates to inside the aircraft. One example is what the flightcrew would see out the window from a forward-facing perspective.

F.1.9 Enhanced Flight Visibility (EFV) (14 CFR 1.1).

The average forward horizontal distance, from the flight deck 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 EFV system.

F.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.

F.1.11 Enhanced Vision System (EVS).

An electronic means to provide a display of the forward external scene topography (the natural or engineered 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.

F.1.11.1 Unlike an EFVS, an EVS does not necessarily provide the additional flight information/symbology required by § 91.176, might not use a HUD 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 § 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 DA/DH or MDA.

F.1.12 Equivalent Display.

In the context of § 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 8055A) with the pilot's 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.

F.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.

F.1.14 Eye Reference Point.

The point in the flightdeck that allows for a finite reference enabling the precise determination of geometric entities that define the layout of the flightdeck and displays.

F.1.15 Field of Regard (FOR) (SAE ARP 5677).

The angular extent of the external world that is represented on a display.

F.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.

F.1.17 Flare Guidance.

Provides explicit command guidance for the pilot to flare the aircraft.

F.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 maneuvering 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.

F.1.19 Flicker (RTCA DO-315A).

High frequency luminance variations.

F.1.20 Flight Path Angle Reference Cue.

A pilot selectable reference cue on the pitch scale displaying the desired approach angle.

F.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.

F.1.22 Flight Visibility (14 CFR 1.1).

The average forward horizontal distance, from the flight deck 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.

F.1.23 Head-Up Display (HUD) (AC 25-11B).

A display system that projects primary flight information (for example, attitude, air data, guidance, etc.) on a transparent screen (combiner) in the pilot's forward field of view, between the pilot and the windshield. This allows the pilot to simultaneously use the flight information while looking along the forward path out the windshield, without scanning the head-down displays. The flight information symbols should be presented as a virtual image focused at optical infinity. Attitude and flight path symbology needs to be conformal (that is, aligned and scaled) with the outside view.

F.1.24 IFR Conditions (14 CFR 1.1).

Weather conditions below the minimum for flight under visual flight rules.

F.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.

F.1.26 Jitter (RTCA DO-315A).

High frequency positional oscillations.

F.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.

F.1.28 Minimum Descent Altitude (14 CFR 1.1).

The lowest altitude specified in an instrument approach procedure, expressed in feet above mean sea level, to which descent is authorized on final approach or during circle-to-land maneuvering until the pilot sees the required visual references for the heliport or runway of intended landing.

F.1.29 Noise Equivalent Power.

Measure of the sensitivity of an optical detector or detector system.

F.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.

F.1.31 Non-Uniformity Correction (NUC).

Calibration of a detector utilizing more than one detector element.

F.1.32 Precision Approach Procedure (14 CFR 1.1).

A standard instrument approach procedure in which an electronic glideslope is provided, such as ILS and PAR.

F.1.33 Primary Flight Display (PFD).

The displays used to present primary flight information.

F.1.34 R_{max}.

The maximum range a radar can detect.

F.1.35 Situation Information (AC 120-29A).

Information that directly informs the pilot about the status of the aircraft system operations or specific flight parameters including flight path.

F.1.36 Synthetic Vision (14 CFR 1.1).

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

F.1.37 Synthetic Vision System (SVS) (14 CFR 1.1).

An electronic means to display a synthetic vision image of the external scene topography to the flightcrew.

F.1.38 SVS Topography.

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.

F.1.39 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.

F.1.40 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.

F.1.41 V_1 (AC 120-62).

The speed selected for each takeoff, based upon approved performance data and specified conditions, which represents:

5. The maximum speed by which a rejected takeoff must be initiated to assure that a safe stop can be completed within the remaining runway, or runway and stopway;
6. The minimum speed which assures that a takeoff can be safely completed within the remaining runway, or runway and clearway after failure of the most critical engine at a designated speed; and
7. The single speed which permits a successful stop or continued takeoff when operating at the minimum allowable field length for a particular weight.

F.1.42 V_r (AC 120-62).

Rotation speed.

F.1.43 Visual References.

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

F.2 Acronyms

AC	Advisory Circular
AFM	Airplane Flight Manual
BIT	Built in Test
CVS	Combined Vision System
DA	Decision Altitude
DH	Decision Height
EASA	European Union Aviation Safety Agency
EFVS	Enhanced Flight Vision System
EVS	Enhanced Vision System
FAA	Federal Aviation Administration
FHA	Functional Hazard Assessment
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
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

MFD	Multi-Function Display
MRAD	Milliradian
ND	Navigation display
NETD	Noise Equivalent Temperature Difference
NUC	Non-uniformity Correction
PFD	Primary Flight Display
PIO	Pilot Induced Oscillation
PSCP	Project Specific Certification Plan
RFM	Rotorcraft Flight Manual
RVR	Runway Visual Range
SSA	System Safety Assessment
STC	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 G. RELATED MATERIAL

G.1 Title 14, Code of Federal Regulations.

The following 14 CFR regulations are related to this AC. You can download the full text of these regulations from the Federal Register website at www.ecfr.gov.

- Part 1, *Definitions and Abbreviations.*
- Part 23, *Airworthiness Standards: Normal Category Airplanes.*
- Part 25, *Airworthiness Standards: Transport Category Airplanes.*
- Part 27, *Airworthiness Standards: Normal Category Rotorcraft.*
- Part 29, *Airworthiness Standards: Transport Category Rotorcraft.*
- Part 91, *General Operating and Flight Rules.*

G.2 FAA Advisory Circular(s).

The following publications are related to the guidance in this AC. You should refer to the latest version for guidance, which is available on the Dynamic Regulatory System (DRS) website at drs.faa.gov/browse.

- AC 20-185A, *Airworthiness Approval of Synthetic Vision Systems, Synthetic Vision Guidance Systems, and Aircraft State Awareness Synthetic Vision Systems*.
- AC 21-16G, *RTCA Document DO-160 versions D, E, F,G "Environmental Conditions and Test Procedures for Airborne Equipment*."
- AC 23-18, *Installation of Terrain Awareness and Warning System (TAWS) Approved for Part 23 Airplanes*.
- AC 23.1309-1E, *System Safety Analysis and Assessment for Part 23 Airplanes.*
- AC 23.1311-1C, *Installation of Electronic Display in Part 23 Airplanes.*
- AC 25-11B, *Electronic Flight Displays.*
- AC 25-23, *Airworthiness Criteria for the Installation Approval of a Terrain Awareness and Warning System (TAWS) for Part 25 Airplanes.*
- AC 25.571-1D, *Damage Tolerance and Fatigue Evaluation of Structure.*
- AC 25.1309-1B, *System Design and Analysis*.

- AC 25.1329-1C, *Approval of Flight Guidance Systems*.
- AC 25.1322-1, *Flightcrew Alerting*.
- AC 25.1523-1, *Minimum Flightcrew*.
- AC 27-1B CHG 1-9, *Certification of Normal Category Rotorcraft.*
- AC 29-2C CHG 9, *Certification of Transport Category Rotorcraft*.
- AC 90-106B, *Enhanced Flight Vision Systems.*
- AC 120-29A, *Criteria for Approval of Category I and Category II Weather Minima for Approach*.
- AC 120-57C, *Surface Movement Guidance and Control System.*
- AC 120-62, *Takeoff Safety Training Aid*.
- AC 120-76E, *Authorization for Use of Electronic Flight Bags*.
- Order 8110.4C CHG 7, *Type Certification.*
- Order 8110.54A, *Instructions for Continued Airworthiness Responsibilities, Requirements, and Contents.*
- Order 8900.1A, *Flight Standards Information Management*.

G.3 Society of Automotive Engineers (SAE) International.

The following SAE Aerospace Recommended Practice (ARP) and Aerospace Standard (AS) documents are related to the guidance in this AC. Unless otherwise specified, use the latest FAA-accepted revision for guidance. If the document is revised after publication of this AC, you should verify that the FAA accepts the subsequent revision or update as an acceptable form of guidance. The documents are available online at: www.sae.org.

- ARP4101, *Flight Deck Layout and Facilities.*
- ARP4102, *Flight Deck Panels, Controls and Displays.*
- ARP4103A, *Flight Deck Lighting for Commercial Transport Aircraft.*
- ARP4105C, *Abbreviations, Acronyms, and Terms for Use on the Flight Deck.*
- ARP4754B, *Guidelines for Development of Civil Aircraft and Systems.*

- ARP4761A, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment.*

- ARP5287, *Optical Measurement Procedures for Airborne Head Up Display (HUD).*

- ARP5288, *Transport Category Airplane Head Up Display (HUD) Systems.*

- ARP5589, *Human Engineering Considerations for Design and Implementation of Perspective Flight Guidance Displays.*

- ARP5677, *Human Engineering Considerations for Airborne Implementation of Enhanced Synthetic Vision Systems.*

- AS8034C, *Minimum Performance Standard for Airborne Multipurpose Electronic Displays*.

- AS8055A, *Minimum Performance Standard for Airborne Head Up Display (HUD).*

G.4 ASTM Consensus Standard(s).

ASTM F3117M-24a, *Standard Specification for Crew Interface in Aircraft* is related to the guidance in this AC. FAA-accepted consensus standards, including any required changes for acceptance, are available online at faa.gov.

G.5 RTCA.

The following RTCA (formerly Radio Technical Commission for Aeronautics) document is related to the guidance in this AC. Unless otherwise specified, use the latest FAA-accepted revision for guidance. If the document is revised after publication of this AC, you should verify that the FAA accepts the subsequent revision or update as an acceptable form of guidance. This document can be ordered online at rtca.org.

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

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

- DO-200, *Standards for Processing Aeronautical Data.*

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

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

- DO-309, *Minimum Operational Performance Standards (MOPS) for Helicopter Terrain Awareness and Warning System (HTAWS) Airborne Equipment*.
- DO-315A, *Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems, and Enhanced Flight Vision Systems.*
- DO-390/EUROCAE 291, *Test Procedures for Quantitative Visual Advantage.*

G.6 **Other Documents.**

MIL-STD-1787D, *Aircraft Display Symbology* is related to the guidance in this AC.

This document can be purchased online at quicksearch.dla.mil/.

OMB Control Number: 2120-0746
Expiration Date: 12/31/2027

Advisory Circular Feedback Form

Paperwork Reduction Act Burden Statement: A federal agency may not conduct or sponsor, and a person is not required to respond to, nor shall a person be subject to a penalty for failure to comply with a collection of information subject to the requirements of the Paperwork Reduction Act unless that collection of information displays a currently valid OMB Control Number. The OMB Control Number for this information collection is 2120-0746. Public reporting for this collection of information is estimated to be approximately 20 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering, and maintaining the data needed, completing, and reviewing the collection of information.
All responses to this collection of information are voluntary. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to: Information Collection Clearance Officer, Federal Aviation Administration, 10101 Hillwood Parkway, Fort Worth, TX 76177-1524.

If you find an error in this Advisory Circular, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by emailing this form to 9-AWA-AVS.AIR.DMO@faa.gov or faxing it to the attention of the N/A at N/A.

Subject: AC 20-167B, Airworthiness Approval of Enhanced Vision System, Enhanced Flight Vision System, and Combined Vision System Equipment

Date: 09/08/2025

Mark all appropriate line items:

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

☐ Recommend paragraph ______ on page _____ be changed as follows:

☐ In a future change to this AC, please cover the following subject:
(Briefly describe what you want added.)

☐ Other comments:

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

Submitted by: ___________________________________ Date: _______________________