The European Organisation for Civil Aviation Equipment
L'Organisation Européenne pour l'Equipement de l'Aviation Civile

MINIMUM AVIATION SYSTEM PERFORMANCE STANDARDS (MASPS) For
ENHANCED VISION SYSTEMS, SYNTHETIC VISION SYSTEMS, COMBINED VISION SYSTEMS
And
ENHANCED FLIGHT VISION SYSTEMS

ED-179
December 2008

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FOREWORD

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CHAPTER 1

PURPOSE AND SCOPE

1.1 INTRODUCTION

This document addresses Enhanced Vision Systems (EVS), Synthetic Vision Systems (SVS), and Combined Vision Systems (CVS) technologies. Currently, only EVS technology incorporating an approved Head-Up Display (HUD) is eligible for operational credit under Title 14 US Code of Federal Regulations (CFR) §91.175 with the Federal Aviation Administration (FAA). An approved combination of EVS and HUD is termed an Enhanced Flight Vision System (EFVS) by the FAA. The European Aviation Safety Agency (EASA) uses the term "EVS" as equivalent to the FAA description of EFVS. While further definitions are in Appendix A, it is important to understand this distinction before reading this document.

Section 1 provides information needed to understand the rationale for system characteristics and requirements. This section also contains typical applications and envisioned operational goals and assumptions necessary to establish a basis for the subsequent sections. It describes typical applications and operational goals, as envisioned by members of RTCA Special Committee 213 and EUROCAE Work Group 79, and establishes the basis for the standards stated in Sections 2 through 4. Definitions and assumptions essential to proper understanding of this document are also provided in this section.

Section 2 describes minimum system performance requirements.

Section 3 contains the minimum performance standards and subsystem/function that is a required element of minimum system performance in Section 2.0. These standards specify the required performance under the standard environmental conditions described.

Section 4 discusses performance evaluations with applicable FAA and EASA regulations, describing the minimum system test procedures to verify system performance compliance (e.g., end-to-end performance verification).

Compliance with these standards is recommended as one means of assuring that the system and each subsystem will perform its intended function(s) satisfactorily under conditions normally encountered in routine aeronautical operations for the environments intended. The Minimum Aviation System Performance Standards (MASPS) may be implemented by one or more regulatory documents and/or advisory documents (e.g., certifications, authorizations, approvals, commissioning, advisory circulars, notices, etc.) and may be implemented in part or in total. Any regulatory application of this document is the sole responsibility of appropriate governmental agencies.

In this document, the term "shall" is used to indicate requirements. An approved design should comply with every requirement, which can be assured by inspection, test, analysis, or demonstration. The term "should" is used to denote a recommendation that would improve equipment, but does not constitute a requirement.

1.1.1 EVS/SVS/CVS Introduction

This MASPS provides the high level system requirements for Enhanced, Synthetic, and Combined Vision Systems when installed in aircraft with the expressed purpose of gaining no additional operational credit. The implication of the term "no additional operational credit" as used throughout this MASPS, is that the applicant cannot take advantage of the existing regulations in the Federal Aviation Regulations/EASA regulations for the various phases of flight through the installation certification of these systems. Refer to the EFVS sections of this MASPS for EVS to gain operational credit. For the FAA, EVS for operational credit is called "EFVS", and the term "EFVS" is used in this document.

The EVS/SVS/CVS subsections of the MASPS focuses on the concept that no additional capability with existing minima will be granted via EVS/SVS/CVS display systems as described within this portion of the MASPS. For example, the IFR approach minima or reduced vision taxi capability are the same for the aircraft regardless if EVS, SVS or CVS is installed.

In order for the following “no additional operational credit’ guidelines to apply, the applicant shall be able to qualify the proposed EVS/SVS/CVS installation’s intended function in terms that do not change the airplane’s existing operational capability or certification basis. This will be one of the key parameters to be scrutinized by FAA during EVS/SVS/CVS flight evaluations when presented with a “No additional operational credit” installation certification.

In this document, Terrain Awareness and Warning System (TAWS) is used indifferently for both TAWS for fixed-wing aircraft and Helicopter TAWS (HTAWS) for rotary-wing aircraft. TAWS is defined in TSO-C151b and HTAWS in DO-309. Installation of TAWS is defined in FAA/AC 23-18 and AC 25-23. Installation of HTAWS is defined in AC 29-2C.

1.1.2 EFVS Introduction

1.1.2.1 The EFVS subsections of this MASPS provide the high level system requirements for Enhanced Flight Vision Systems when installed in aircraft with the expressed purpose of gaining additional operational credit.

1.1.2.2 The requirements of this MASPS may be global in nature and have international implications; however, they are written to meet the definitions, intended functions, and operational application defined in 14 CFR §1.1, §91.175 (l) and (m), §121.651, §125.381, and §135.225 as of Amendment 91-281 (69 FR 1620, January 9, 2004). Similar references are found in EU Ops Subpart E, Appendix 1 to OPS 1.430 (h). It should be noted that the European Aviation Safety Agency’s (EASA) terminology and operational credit may differ from that of the United States. EASA uses the term Enhanced Vision System (EVS) to describe a system that has the same elements, features and characteristics as an Enhanced Flight Vision System (EFVS) certified by the FAA for use in the United States. EASA’s operational concept and corresponding requirements may also be slightly different from those of the FAA.

1.1.2.3 The EFVS subsections of this MASPS specifically focus on standards to meet FAA and EASA requirements for an Enhanced Flight Vision System. Other guidance material is available (see References). This MASPS is intended to be complementary to these other materials, and is not meant to replace or conflict with these other materials. Conflicts between this MASPS and other material should be resolved on a case-by-case basis.

1.2 EVS/SVS/CVS

1.2.1 EVS/SVS/CVS Overview

Notional system diagrams accompany the EVS/EFVS and SVS descriptions. It is important to note the flight guidance system (FGS) contribution is not part of this MASPS, but an integral part of the overall display system. This distinction will be portrayed in the succeeding diagrams. FGS criteria may be found in documents such as FAA Advisory Circular (AC) 25.1329A and EASA Accountable Means of Compliance (AMC) 25.1329.

1.2.1.1 EVS Overview

An Enhanced Vision System (EVS) is an electronic means to provide the flight crew with a sensor-derived or enhanced image of the external scene through the use of imaging sensors such as forward looking infrared, millimeter wave radiometry, millimeter wave radar, and/or low light level image intensifying. A notional diagram for EVS is shown below. In this example, EVS does not have to be integrated with a flight guidance system.

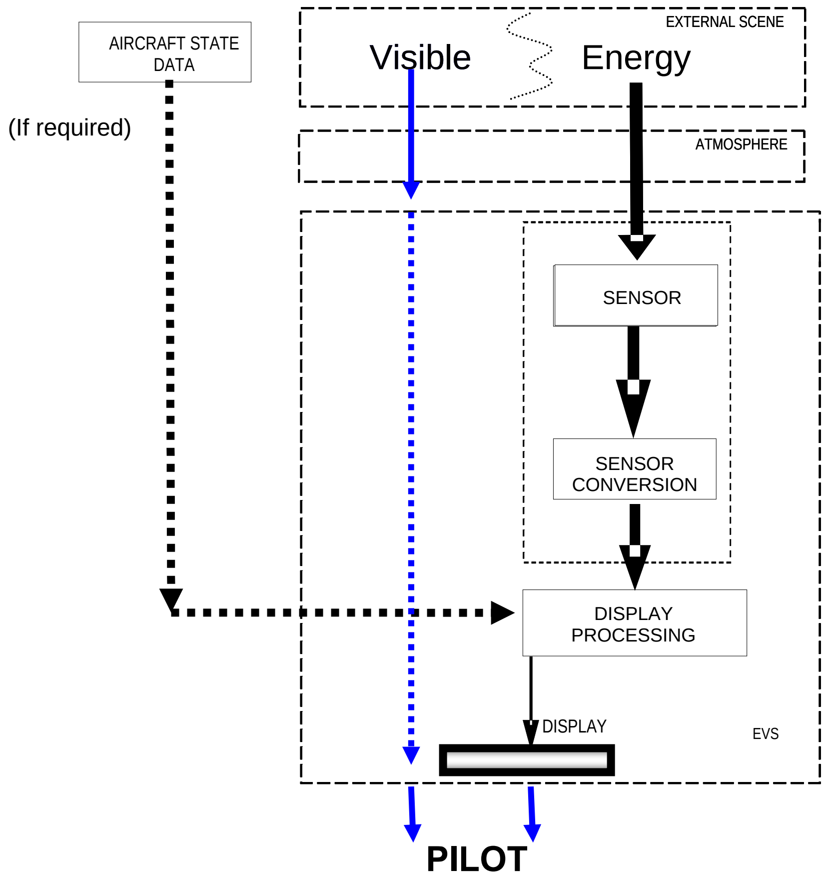


FIGURE 1: EVS DIAGRAM

1.2.1.2 Synthetic Vision System Overview

A Synthetic Vision System (SVS) is an electronic means to display a computer-generated image of the applicable external topography from the perspective of the flight deck that is derived from aircraft attitude, altitude, position, and a coordinate-referenced database. Currently, the application of synthetic vision systems is through a primary flight display, and from the perspective of the flight deck (egocentric). This MASPS also addresses exocentric views with respect to secondary displays. A notional diagram for SVS is shown in Figure 2.

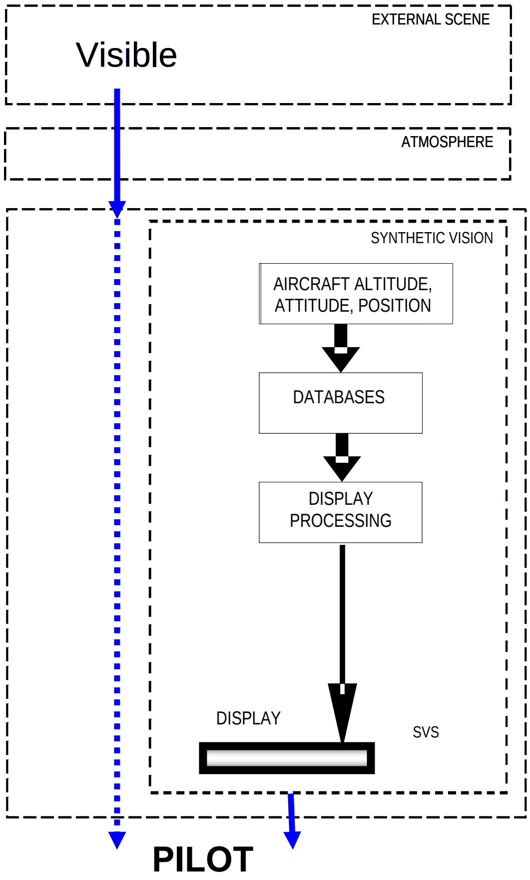


FIGURE 2: SVS DIAGRAM

1.2.1.3 Combined Vision System Overview

A Combined Vision System (CVS) is a combination of synthetic and enhanced vision systems. The current integration concepts typically utilize a synthetic picture for higher altitudes and enhanced for lower altitudes down to the ground. For example, on an approach, most of the arrival and/or the procedure turn would utilize the SVS picture, but somewhere between the final approach fix and the runway, the picture would gradually transition from SVS to EVS either for SVS picture validation or simply to "see" the runway environment earlier.

Some examples of a CVS could include, but are not limited to, database driven synthetic vision images combined with real-time sensor images superimposed and correlated on the same display. This could also include selective blending of the two technologies based on the intended function of the Combined Vision System seeking certification.

1.2.1.4 EVS/SVS/CVS Installed Displays (EFIS, MFD, Class 3 EFB)

This MASPS breaks down the EVS, SVS and CVS into three general categories of display systems as installed on FAA and EASA certified aircraft. These categories include but are not limited to the following:

1.2.1.4.1 EVS/SVS/CVS Primary Displays: EVS, SVS, or CVS functionality superimposed on the Electronic Flight Instrument System (EFIS), for example the Primary Flight Display (PFD) as installed in the flight deck. In this configuration for example, the EVS, SVS, or CVS image could be merged into the sky/ground shading of the Attitude Direction Indicator as one implementation. In addition to the traditional HDD (Head-Down Display) PFD, this type of superimposed display could also be associated with a HUD or equivalent display system using EVS, SVS, or CVS capabilities.

1.2.1.4.2 EVS/SVS/CVS Secondary Displays: EVS, SVS, or CVS functionality that can be selected on a Multi-Function Display (MFD) or Navigation Display (ND) as one of many stand-alone type formats available in the flight deck. In other words, an EVS, SVS, or CVS image could be one selection on the MFD, while an Electrical Synoptic, for example, could be another selection on the same MFD.

1.2.1.4.3 EVS/SVS/CVS Electronic Flight Bag: EVS, SVS, or CVS functionality installed on Class 3 Electronic Flight Bag (EFB) displays. While similar in concept to the MFD, these EFB systems are, in general, limited due to the nature of the installation constraints of these devices. EFB using EVS technologies may present unique certification challenges such as alignment or positioning concerns relating to the EFB installation.

1.2.2 EVS/SVS/CVS General Operation

The pilot's ability to see and use the required primary flight display information such as primary attitude, airspeed, altitude, command bars, etc., shall not be hindered or compromised by the EVS/SVS/CVS image. Great care should be exercised when adding additional features or symbology as well as the placement of required primary flight display information.

1.2.3 EVS/SVS/CVS Intended Function

The intended function of EVS/SVS/CVS is to provide a supplemental view of the external scene to provide the crew with an awareness of terrain, obstacles, and relevant cultural features (which may include the runway and airport environment). Additional intended functions (for example, terrain alerting) may be defined according to AC 25-11A, AMJ 25-11, AC 23-26, and 14 CFR §23.1301.

1.2.4 EVS/SVS/CVS Assumptions

Since no additional operational credit is allowed with this equipment, crews are expected to follow the existing operational procedures and adhere to all published minimums.

NOTE: *The system and safety criteria for each specific part and class of aircraft provide the necessary guidance for the required level of safety for each phase of flight and by type of operation.*

1.3 EFVS

1.3.1 EFVS Overview

1.3.1.1 Under FAA regulations, an Enhanced Flight Vision System (EFVS), as defined in 14 CFR §1.1, is “an electronic means to provide a display of the forward external scene topography (the natural or manmade features of a place or region especially in a way to show their relative positions and elevation) through the use of imaging sensors, such as a forward looking infrared, millimeter wave radiometry, millimeter wave radar, low light level image intensifying.” For the purposes of the present document, all of these sensors will be categorized as either active or passive.

Under EASA regulations, the Enhanced Vision System (EVS) consists, for the purpose of this guidance material, of an electronic means of displaying a real-time image of the external scene through the use of external sensors. The image will also be repeated on a certified display on the pilot not-flying side.

Both systems incorporate HUD / FGS technologies, which have guidance criteria in other documents and are not repeated in this MASPS. A notional diagram for EFVS is shown in Figure 3.

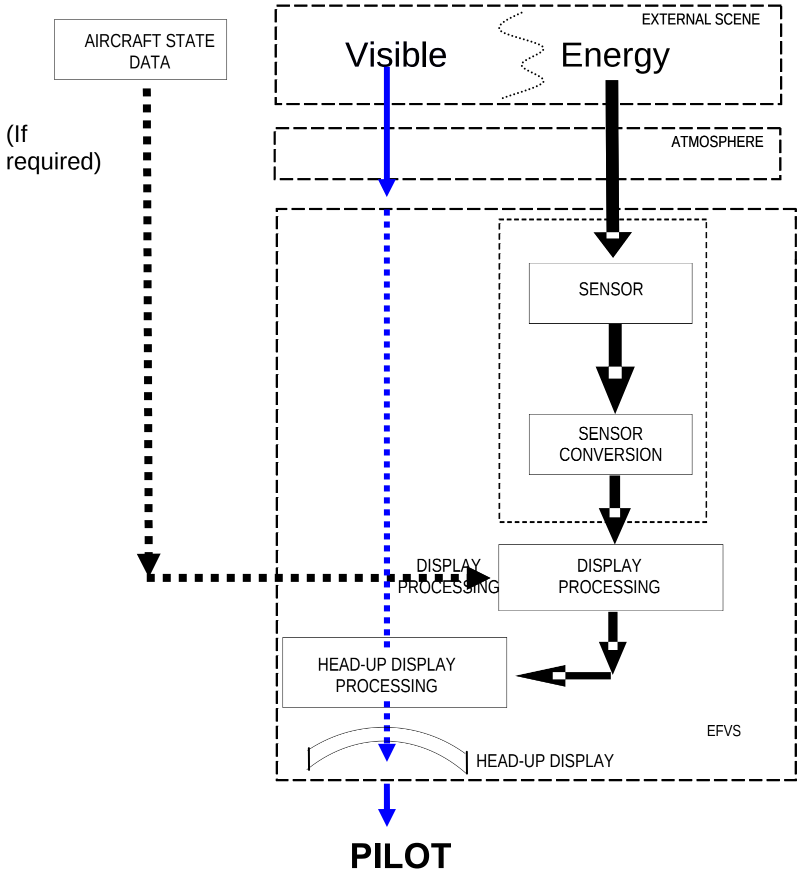


FIGURE 3: EFVS DIAGRAM

1.3.1.2 Under FAA regulations, Amendment 91-281 to Title 14 of the CFR also introduced the term "Enhanced Flight Visibility." Enhanced Flight Visibility is defined in 14 CFR §1.1 as the "average forward horizontal distance, from the cockpit of an aircraft in flight, at which prominent topographical objects may be clearly distinguished and identified by day or night by a pilot using an enhanced flight vision system." An EFVS, then, is the means by which the pilot meets the enhanced flight visibility requirement.

Under EASA regulations (EU-OPS Sub-Part E), the term Enhanced Flight Visibility is not used. Operational credit is achieved by reducing the RVR required to commence the approach.

1.3.1.3 Under US regulations, an EFVS used to conduct operations under §91.175(l) and (m), §121.651, §125.381, and §135.225 shall have an FAA type design approval, or for a foreign-registered aircraft, the EFVS shall comply with all of the EFVS requirements of the U.S. regulations. Under §91.175(m), an EFVS is an installed airborne system that includes:

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

Under EASA regulations, an EVS used to conduct operations under EU-OPS Sub-Part E shall have an EASA type design approval or for a foreign-registered aircraft, the EVS shall comply with all of the EVS requirements of the European regulations.

1.3.1.4 For the purpose of this document, a HUD is assumed to be the display used per current regulations. For an equivalent display other than a HUD, a proof of concept demonstration would have to be conducted to determine the operational and airworthiness criteria.

1.3.1.5 In addition to the sensor imagery, at least the following specific aircraft flight information shall be displayed:

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

1.3.2 EFVS Operational Application

1.3.2.1 Under FAA regulations, the use of EFVS for flight operations in instrument meteorological conditions (IMC) where operational credit is desired has been defined in14 CFR §91.175(l) and (m), §121.651, §125.381, and §135.225. These regulations provide the basis for using an FAA-approved EFVS to operate below Decision Height/Decision Altitude (DH/DA) or Minimum Descent Height/Minimum Descent Altitude (MDH/MDA) down to 100 feet height above touchdown zone elevation (TDZE), based on the pilot determining that the enhanced flight visibility is at least that published for the instrument approach being used, and that the visual cues specified in §91.175 (l) can be seen using the EFVS display. The "operational credit" that is possible with an FAA-approved EFVS is that such approaches can be conducted even when actual flight visibility is less than prescribed in the instrument approach procedure being used.

Under EASA regulations (EU-OPS Sub-Part E), the use of EVS for flight operations in IMC is defined. These regulations provide the basis for using an EASA-approved EVS to operate below DH/MDH down to 100 feet height above touchdown zone elevation in reduced visibility conditions.

1.3.2.2 Under FAA regulations, published approach minima remain unchanged in this operations concept.

Under European regulation, published approach minima are adjusted by a reduction in the required RVR in accordance with the table in EU-OPS Sub-Part E (this equates to an approximate reduction of 1/3 RVR compared to approaches not utilizing EVS).

1.3.3 EFVS General Operation

EFVS may be used in all phases of flight, including surface movement, to improve a pilot's ability to see objects and features in the surrounding environment. The operational applications and goals described in this section, however, are limited to a discussion of how EFVS is used to operate below DH/DA or MDH/MDA down to 100 feet height above TDZE from an other than Category II or III straight-in landing instrument approach procedure. This portion of the approach phase of flight is where operational credit for EFVS is given under Amendment 91-281 (69 FR 1620 January 9, 2004) to 14 CFR 91.175 (l) and (m), 121.651, 125.381, and 135.225. An "other than Category II or III straight-in landing instrument approach procedure" may be offset up to 30 degrees from the extended runway centerline depending on the type of instrument approach procedure (up to 3 degrees for ILS, 15 degrees for GPS, and 30 degrees for VOR or NDB). The instrument portion of an instrument approach procedure ends at DH/DA or MDH/MDA, and the visual segment begins just below DH/DA or MDH/MDA and continues to the runway. Under the current regulations, there are two means of operating below DH/DA or MDH/MDA down to 100 feet above TDZE from an other than Category II or III straight-in landing instrument approach procedure: by natural vision or by using an FAA-certified EFVS.

1.3.3.1 Instrument approach operations without EFVS

1.3.3.1.1 When natural vision is used, an operator conducts the instrument approach procedure down to DH/DA or MDH/MDA in accordance with the published instrument approach procedure and that operator's approved procedures and callouts. A pilot may either be head down or head up, depending on how the aircraft is equipped. Prior to reaching DH/DA or MDH/MDA, the pilot's primary references for maneuvering the airplane are the aircraft instruments, displays, and onboard navigation system.

1.3.3.1.2 At DH/DA or MDH/MDA, if no HUD is installed in the airplane, the pilot transitions from using head down displays of aircraft state and flight path information to looking outside along the flight path. The steps in this task sequence include head and eye movement from cockpit displays to the outside environment, visual accommodation, visual search for relevant objects in the outside visual scene, and allocation of attention to various elements in the visual scene. If a HUD is installed, the pilot continues looking through the HUD, eliminating head down to head up movement and visual accommodation. Visual search through the HUD and allocation of attention between HUD symbology and other elements in the outside visual scene are still part of the pilot task sequence. At DH/DA or MDH/MDA, the pilot makes a decision whether to continue descending below DH/DA or MDH/MDA.

Under FAA regulations, based on the requirements of 14 CFR §91.175(c), §121.651, §125.381, and/or §135.225, as applicable, those requirements are as follows:

- The aircraft shall be <u>continuously</u> in position from which a descent to landing can be made
- On the intended runway
- At a normal rate of descent
- Using normal maneuvers
- For §121 and §135 operators, the descent rate shall allow touchdown to occur within the touchdown zone.
- The **flight visibility** may not be less than the visibility prescribed in the instrument approach procedure. Flight visibility is assessed using natural vision and means the average forward horizontal distance, from the cockpit of an aircraft in flight, at which prominent unlighted objects may be seen and identified by day and prominent lighted objects may be seen and identified by night.

- The required visual references shall be distinctly visible and identifiable. (See Table 1)

Under EASA regulations, a pilot may not continue an approach below DA/DH or MDA/MDH unless at least one of the visual references listed in Table 2 for the intended runway is distinctly visible and identifiable to the pilot.

TABLE 1: REQUIRED VISUAL REFERENCES, 14 CFR § 91.175 (C) AND (L)

Required Visual References Using Natural Vision (14 CFR § 91.175 (c))	**Required Visual References Using an Enhanced Flight Vision System (14 CFR § 91.175 (l))**
For operation below DA/DH or MDA/MDH – At least one of the following visual references for the intended runway must be distinctly visible and identifiable: Approach light system Threshold Threshold markings Threshold lights Runway end identifier lights Visual approach slope indicator Touchdown zone Touchdown zone markings Touchdown zone lights Runway Runway markings Runway lights	**For operation below DA/DH or MDA/MDH –** The following visual references for the intended runway must be distinctly visible and identifiable: Approach light system ***OR*** Visual references in **BOTH** paragraphs 91.175(l)(3)(ii)(A) and (B) -- (l)(3)(ii)(A) The runway threshold, identified by at least one of the following – -- beginning of the runway landing surface, -- threshold lights, or -- runway end identifier lights **AND** (l)(3)(ii)(B) The touchdown zone, identified by at least one of the following – -- runway touchdown zone landing surface, -- touchdown zone lights, -- touchdown zone markings, or -- runway lights.
Descent below 100 feet height above TDZE – At least one of the following visual references for the intended runway must be distinctly visible and identifiable: Approach light system, as long as the red terminating bars or red side row bars are also distinctly visible and identifiable Threshold Threshold markings Threshold lights Runway end identifier lights Visual approach slope indicator Touchdown zone Touchdown zone markings Touchdown zone lights Runway Runway markings Runway lights	**Descent below 100 feet height above TDZE –** The flight visibility must be sufficient for the following to be distinctly visible and identifiable to the pilot without reliance on the enhanced flight vision system to continue to a landing: The lights or markings of the threshold ***OR*** The lights or markings of the touchdown zone

TABLE 2: REQUIRED VISUAL REFERENCES, EU-OPS SUB-PART E

Required Visual References Using Natural Vision EU-OPS Sub-Part E	Required Visual References Using an Enhanced Flight Vision System EU-OPS Sub-Part E
For operation below DA/DH or MDA/MDH – A pilot may not continue an approach below MDA/MDH unless at least one of the following visual references for the intended runway is distinctly visible and identifiable to the pilot: Elements of the approach light system; The threshold; The threshold markings; The threshold lights; The threshold identification lights; The visual glide slope indicator; The touchdown zone or touchdown zone markings; The touchdown zone lights; Runway edge lights; or Other visual references accepted by the Authority.	**For operation below DA/DH or MDA/MDH –** A pilot using an enhanced vision system certificated for the purpose of this paragraph may: (i) Continue an approach below DA/DH or MDA/MDH to 100 feet above the threshold elevation of the runway provided that at least one of the following visual references is displayed and identifiable on the enhanced vision system: (A) Elements of the approach lighting; **OR** (B) The runway threshold, identified by at least one of the following: the beginning of the runway landing surface, the threshold lights, the threshold identification lights; and the touchdown zone, identified by at least one of the following: the runway touchdown zone landing surface, the touchdown zone lights, the touchdown zone markings or the runway lights.
Descent below 100 feet height above TDZE – As above for descent below DA/DH or MDA/MDH	**Descent below 100 feet height above TDZE –** A pilot may not continue an approach below 100 feet above runway threshold elevation for the intended runway, unless at least one of the visual references specified below is distinctly visible and identifiable to the pilot without reliance on the enhanced vision system: (A) The lights or markings of the threshold; or (B) The lights or markings of the touchdown zone.

1.3.3.1.3 Provided these requirements are met, the pilot may continue descending below DA/DH or MDA/MDH down to 100 feet above TDZE. As the pilot approaches DA/DH or MDA/MDH, he or she looks for the approach lighting system, if there is one, as well as the runway threshold and touchdown zone lights, markings, surfaces, and features. These visual references not only contribute to assessment of flight visibility, but they help the pilot align the aircraft with the runway and provide position, lateral roll, rate of closure, and distance remaining information. This visual information serves as independent verification of the information provided by the aircraft displays and systems.

1.3.3.1.4 At 100 feet above the TDZE, the pilot again makes a determination about whether the flight visibility is sufficient to continue the approach as well as whether the required visual references are distinctly visible and identifiable before descending below 100 feet. In the visual segment, which extends from DA/DH or MDA/MDH down to the runway, the primary reference for maneuvering the airplane is based on what the pilot sees visually. Supporting information is provided by aircraft instruments, displays, and the onboard navigation system.

1.3.3.2 Instrument approach operations with EFVS

1.3.3.2.1 Under FAA regulations, EFVS operations under 14 CFR §91.175 (l) and (m), §121.651, §125.381, and §135.225 are analogous to those conducted with natural vision. Amendment 91-281 (69 FR 1620, January 9, 2004) of the regulations, referenced above, authorizes EFVS to be used on other than Category II and III straight-in landing instrument approach procedures. Here again, the operator conducts the instrument approach procedure down to DA/DH or MDA/MDH in accordance with the published instrument approach procedure and that operator's approved procedures and callouts. Prior to reaching DH or MDA, the pilot's primary references for maneuvering the airplane are the aircraft instruments, displays and onboard navigation system.

Under EASA regulations, EFVS (European "EVS") operations are conducted under EU-OPS Sub-Part E and are analogous to those conducted with natural vision. They are authorized to be used for ILS, MLS, PAR, GLS and APV approaches with a DH/DA no lower than 200 feet, or an approach flown using approved vertical flight path guidance to a MDH or DH no lower than 250 feet. Here again, the operator conducts the instrument approach procedure down to DH/DA or MDA/MDH in accordance with the published instrument approach procedure and that operator's approved procedures and callouts. Prior to reaching DH/DA or MDH/MDA, the pilot's primary references for maneuvering the airplane are the aircraft instruments, displays and onboard navigation system.

1.3.3.2.2 For EFVS operations, the sensor imagery and required flight information and symbology shall be displayed on a HUD or an equivalent display so that the pilot flies both the instrument and visual segments head up, eliminating head down to head up transition and visual accommodation time. An equivalent display shall present the EFVS sensor imagery and aircraft flight symbology required by 14 CFR §91.175 (m) so that they are clearly visible to the pilot flying in his or her normal position and line of vision and looking forward along the flight path. In other words, an equivalent display shall be some type of head up presentation of the required information. The EFVS display shall also be conformal. That is, the sensor imagery, aircraft flight symbology and other cues that are referenced to the imagery and external scene shall be aligned with and scaled to the external view. EFVS operations require the pilot to accomplish several visual-based judgment and control tasks in quick succession. These include using the imagery, flight reference information, and eventually the outside view at the same time. The pilot shall be able to look for the outside visual references in the same location as they appear in the EFVS image and readily see them as soon as visibility conditions permit, without delays or distraction due to multiple head up and head down transitions. Scanning between head up and head down views can be distracting, increase pilot workload and potentially degrade path performance during a critical phase of flight. These effects are mitigated by displaying the EFVS imagery and flight information on the HUD.

1.3.3.2.3 At DA/DH or MDA/MDH, the pilot makes a decision whether to continue descending below DA/DH or MDA/MDH using an EFVS based on all of the requirements of the applicable regulations cited above. Those requirements are as follows:

Under US regulations:

- The aircraft must be continuously in position from which a descent to landing can be made:
  - On the intended runway
  - At a normal rate of descent
  - Using normal maneuvers
  - For Part 121 and 135 operators, the descent rate must allow touchdown to occur within the touchdown zone.
- The enhanced flight visibility may not be less than the visibility prescribed in the instrument approach procedure. Enhanced flight visibility is assessed using an EFVS (not natural vision) and means the average horizontal distance, from the cockpit of an aircraft in flight, at which prominent topographical objects may be clearly distinguished and identified by day or night by a pilot using an enhanced flight vision system.

- The required visual references must be distinctly visible and identifiable. (See Table 1) These visual reference requirements are more stringent than those required by § 91.175 (c) for natural vision because EFVS displays may not be able to display the color of the lights used to identify specific portions of the runway.
- At 100 feet height above TDZE, the required visual references must be seen without relying on the EFVS. In other words, they must be seen with natural vision. (See Table 1)

Under European regulations, a pilot may not continue an approach below DA/DH or MDA/MDH unless at least one of the visual references listed in Table 2 for the intended runway is distinctly visible and identifiable to the pilot. EU-OPS specifies the visual references for descent below DA/DH/MDA/MDH as above and additional requirements are specified at 100 feet as listed in Table 2.

1.3.3.2.4 The portion of the visual segment in which EFVS may be used in lieu of natural vision extends from DA/DH or MDA/MDH down to 100 feet height above TDZE (Figure 4). Provided the requirements identified above are met, the pilot may continue descending below DA/DH or MDA/MDH down to 100 feet above TDZE. Here again, as the pilot approaches DA/DH or MDA/MDH, he or she looks for the approach lighting system, if there is one, as well as the runway threshold and touchdown zone lights, markings, surfaces, and features using the EFVS. These visual references not only contribute to assessment of enhanced flight visibility, but they help the pilot align the aircraft with the runway and provide position, lateral roll, rate of closure, and distance remaining information just as they do when natural vision is used. The information provided by aircraft displays and systems serves as independent verification of the visual information provided by the EFVS.

1.3.3.2.5 At 100 feet above the TDZE, the visual transition point, (Figure 4) the pilot makes a determination about whether the flight visibility (under US regulations) is sufficient to continue the approach and distinctly identify the required visual references using natural vision. At 100 feet height above TDZE, the pilot can no longer rely entirely on EFVS or use enhanced flight visibility (under US regulations) to continue descent.

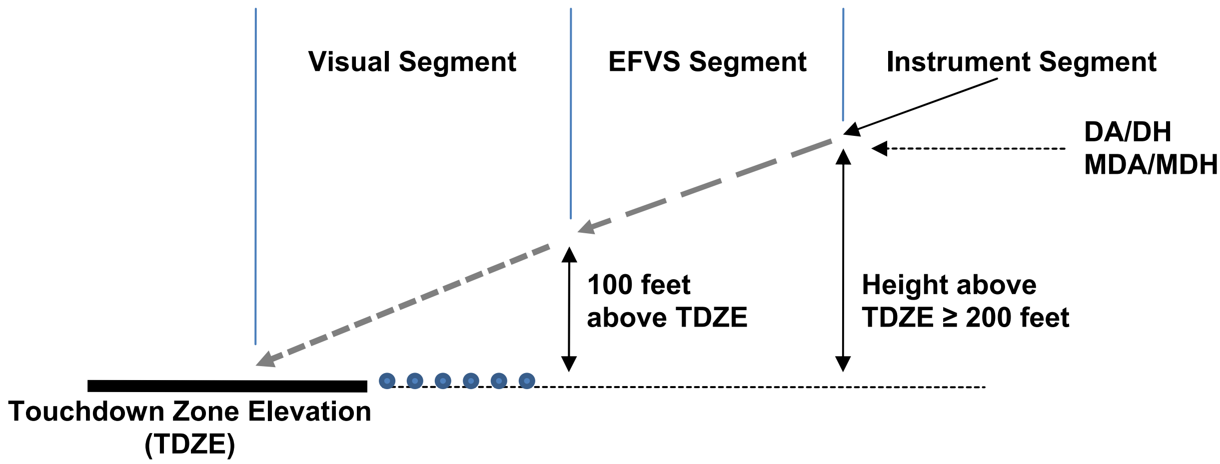


FIGURE 4: EFVS AND VISUAL TRANSITION POINTS

1.3.3.2.6 It should be noted that current regulations do not require that the EFVS be stowed or that the sensor image be removed from the HUD in order to meet this requirement. As long as the pilot can see the required visual references that would normally be seen through the HUD with natural vision, the regulatory requirement can be met. Lights and other features of the approach lighting system, runway threshold, or touchdown zone are often distinguishable from the sensor image as the aircraft gets closer to them. The pilot should, however, be able to easily and quickly declutter the EFVS or remove the sensor image at any time it is deemed necessary or appropriate.

1.3.3.2.7 In the EFVS portion of the visual segment, which extends from DA/DH or MDA/MDH down to 100 feet height above TDZE, the primary reference for maneuvering the airplane is based on what the pilot sees visually through the EFVS. From 100 feet to the runway, the primary reference for maneuvering the airplane is based on what the pilot sees with natural vision. Supporting information is provided by the flight path vector, flight path angle reference cue, onboard navigation system, and other imagery and flight symbology displayed on the EFVS. The flight path vector provides information relevant to the vertical path.

Under FAA regulations, approaches with no published vertical flight path or for flying a specific vertical flight path below DA/DH or MDA/MDH, the flight path angle reference cue may be used to position the aircraft on an appropriate glidepath to the touchdown zone. This is done by presetting the flight path angle reference cue to an angle consistent with the published approach procedure, the visual approach slope indicator, or the precision approach path indicator. The pilot would continue to fly at the MDA/MDH until the flight path angle reference cue is positioned over the desired touchdown point in the touchdown zone of the runway image as it appears on the EFVS. The pilot would adjust the rate of descent until the flight path vector is positioned over the touchdown zone and the flight path angle reference cue. Use of the flight path angle reference cue in this manner requires that it be displayed with the pitch scale and that the desired flight path angle be selectable by the pilot for the appropriate descent angle.

NOTE: *There are many approaches where the published approach descent angle is different from the published Visual Glide Slope Indicator (VGSI) angle. An operational procedure may be required to address such discrepancies when using the Flight Path Vector and Flight Path Angle reference cue as described.*

Under EASA regulations, approaches utilizing EVS are not permitted without a published vertical flight path.

1.3.3.2.8 FAA regulations do not require that the sensor image and flight information from the EFVS be presented to the non-flying pilot, nor do they preclude it. EFVS equipage may vary. Some operators may choose to equip with a single EFVS display. Others may install an EFVS display and a separate repeater display located in or very near the primary field of view of the non-flying pilot. Still others may elect to equip with dual EFVS displays.

EASA regulations require a separate repeater display located in or very near the primary field of view of the non-flying pilot. Operators may elect to equip with dual EVS displays.

1.3.3.2.9 Procedures should be developed for EFVS operations appropriate to the installed equipment and the operation to be conducted. In particular, procedures should support appropriate levels of crew coordination and pilot/crew decision making in the segments from final approach fix to DA/DH or MDA/MDH, in the EFVS segment from DA/DH or MDA/MDH down to 100 feet height above TDZE, and the point at which a decision to rely on natural vision is made – whether that is at 100 feet height above TDZE or prior to reaching that point. Additionally, each EFVS has a specified limit to the field of regard which may affect its use during final approach or in crosswinds.

1.3.4 EFVS Intended Function

1.3.4.1 The intended function of an EFVS system as described in this MASPS is to improve visibility during low-visibility conditions. Specifically, the EFVS is used to visually acquire the references required to operate below the MDA/MDH or DA/DH as described in §91.175(l) and EU OPS Sub-Part E. The purpose of the EFVS sensor is to provide a visual advantage over the pilot's out-the-window view. In low visibility conditions, the "enhanced flight visibility" should exceed the "flight visibility" and the required visual references should become visible to the pilot at a longer distance in the EFVS than out-the-window.

1.3.4.2 The EFVS is not intended to change the technologies or procedures already used to safely fly the aircraft down to the MDA/MDH or DA/DH. The EFVS complements other instrument approach equipment by providing a means for the pilot to see (with the EFVS) the required visual references that might otherwise not be visible.

1.3.5 EFVS Assumptions

This document identifies generic system and sub-system performance, safety and redundancy requirements for the use of this technology. The operational rules provide the context for acceptable types of operations, and in some cases the top level performance and equipage of the aircraft or airport. The system and safety criteria also provide the necessary guidance for the required level of safety for each phase of flight and by type of operation.

1.4 VERIFICATION PROCEDURES

1.4.1 The verification procedures specified in this document are intended as an acceptable means of demonstrating compliance with the performance requirements. Although test procedures are normally associated with performance verification, it is recognized that other methods (e.g., analysis, simulation, inspection) may be used, and may be more appropriate to the large-scale systems addressed in this MASPS. However, it is desirable that such other methods be validated by procedures involving actual measurements of the system.

1.4.2 Alternatives to the procedures specified herein may be used if it can be demonstrated that they provide at least equivalent information. Subsystem verification is useful as subsystems are added during system buildup and to ensure continued subsystem performance as it relates to overall system performance.

1.5 REFERENCE DOCUMENTS

References applicable to specific systems are given in their corresponding sections. Technical references applicable to specific systems are given in Appendix B. The System Safety Requirements Logic and examples are provided in Appendix C. EFVS Minimum System Performance Standard Rationale is explained in Appendix D. EVS/SVS/CVS Minimum System Performance Standard Rationale is explained in Appendix E. A sample EFVS Flight Test Plan is provided in Appendix F.

CHAPTER 2

SYSTEM PERFORMANCE REQUIREMENTS

2.1 ENHANCED VISION SYSTEMS (EVS) / SYNTHETIC VISION SYSTEMS (SVS) / COMBINED VISION SYSTEMS (CVS)

2.1.1 EVS/SVS/CVS General Requirements

This portion of the MASPS provides the system performance of the EVS/SVS/CVS system by first describing the cockpit display that these types of images are rendered upon. Section 2.1.2 then provides the requirements for EVS/SVS/CVS images as shown on these cockpit display categories.

The following general requirements apply to all EVS/SVS/CVS implementations detailed in this section.

a. The system shall have a means to automatically or manually control display brightness.

b. The system shall not degrade presentation of essential flight information.

c. A system modified to display EVS/SVS/CVS shall continue to meet requirements of original approval (if applicable).

d. The system shall not adversely affect any other installed aircraft system.

e. The system shall be shown to perform its intended function in each aircraft environment where system approval is desired. For example, if the system is intended to perform in (or after exposure to) known icing conditions, a means may be required to keep the EVS sensor window clear of ice accretion.

2.1.1.1 Display Implementation

Enhanced, Synthetic and or Combined Vision Systems (EVS/SVS/CVS) may be incorporated into differing display types installed in the cockpit. There are unique tactical and strategic requirements for each of these displays and the types of the display are categorized in the sections below. See FAA AC 25-11A for more information on electronic displays.

2.1.1.1.1 Primary Displays

Primary Displays are those cockpit displays used to provide information needed to guide and control the aircraft and provide the aircraft altitude, attitude and airspeed indications. See FAA AC 25-11A Appendix 1 for more information of what constitutes primary information.

2.1.1.1.1.1 PFD (Primary Flight Display)

EVS/SVS/CVS may be implemented on the primary flight display. The following requirements apply to EVS/SVS/CVS implemented on this display.

a. The PFD shall remain subject to all applicable primary flight information rules and guidance for the category of aircraft.

b. The image or loss thereof shall not adversely affect the PFD functionality.

c. The displayed image should be aligned with airplane's inertial axis, physical axis or as appropriate for the intended function and may be variable and/or "phase of flight" dependent. The relationship between the image and the airplane's heading angle, pitch angle, roll angle, and track angle should be recognizable by the flight crew and not be misleading.

d. The displayed image and symbology may have different scaling between the vertical and lateral axis. Scaling differences shall be evaluated to ensure the image is not misleading. All spatially referenced symbology within each axis shall be sufficiently scaled and aligned with the imagery so as not to present any misleading information to the pilot.

e. Variable field of regard may be acceptable but it should be evaluated to ensure that the displayed image is not distracting or misleading and does not adversely affect crew workload.

f. The system shall provide a clearly visible zero pitch reference line, distinct in visual appearance relative to any possible terrain, obstacle, or cultural feature display appearance.

2.1.1.1.1.2 Head-Up Display (HUD)

EVS/SVS/CVS may be implemented on a head-up or equivalent display. Due to the tactical nature of the HUD, the following requirements apply to EVS/SVS/CVS implemented on this display.

a. The HUD shall remain subject to all applicable rules and guidance for the category of aircraft.

b. The safety and performance of the pilot tasks associated with the use of the pilot compartment view shall not be degraded by the display of imagery on the HUD. Imagery on the HUD shall be conformal with the real world and appropriate for the system's intended function accounting for possible aircraft attitudes and wind effects. SAE design standards for HUD symbology, optical elements and video imagery are also prescribed with SAE Aerospace Standard (AS) 8055, SAE Aerospace Recommended Practice (ARP) 5288 and SAE ARP 5287. Specific design standards should be applied for resolution and line width, luminance and contrast ratio, chromaticity, and grayscale. Pilot tasks which shall not be degraded by the imagery include:

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

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

2.1.1.1.2 Secondary Displays

EVS/SVS/CVS may be implemented with ego-centric "inside aircraft" views or exo-centric "outside aircraft" viewpoints on the secondary displays. The following requirements apply to EVS/SVS/CVS implemented on these types of displays.

a. The display shall remain subject to all applicable rules and guidance for the category of aircraft.

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

c. For secondary displays, SVS depictions using the pilot's view looking forward and that include primary display information need to be approved accordingly. For example, if PFD information is displayed, it should meet PFD integrity levels

d. EVS/SVS/CVS image, or loss thereof, shall not adversely affect other approved secondary display functionality (e.g., navigation display).

2.1.1.1.3 Electronic Flight Bag (EFB)

EVS/SVS/CVS shall only be implemented on EFB displays which are Class 3.

a. The display shall remain subject to all applicable EFB guidance for such displays and their installation.

b. For EFB's, SVS depictions using the pilot's view looking forward and that include primary display information need to be approved accordingly. For example, if PFD information is displayed, it should meet PFD integrity levels.

c. EVS/SVS/CVS image, or loss thereof, shall not adversely affect other approved EFB functionality.

2.1.2 EVS/SVS/CVS System Requirements

These systems are installed such that they don't qualify for additional operational credit over and above that already certified. They are installed on a non-interference basis and shall meet the following two regulatory requirements; 1) that they don't create or contribute to an unsafe condition, and 2) that they perform their intended function.

2.1.2.1 EVS

Enhanced Vision Systems (EVS) require a real-time imaging sensor and display that provides demonstrated vision performance for its intended function which shall be clearly defined. The design and installation safety levels should be appropriate for the system's intended function.

The following requirements apply to EVS installations:

a. The EVS depiction shall be crew de-selectable (if on the Primary Display, the pilot should be able to easily and quickly declutter the EVS or remove sensor image). For an EVS image displayed on a HUD, a control shall be provided which permits the pilot flying to deactivate and reactivate the display of the EVS image on demand without removing the pilot's hands from the primary flight controls (yoke or equivalent) or thrust control.

b. The display status of EVS, either through crew de-selection or as a result of a failure, shall be clearly indicated or obvious to the crew.

NOTE: *Consideration should be given to recording the EVS display status in a flight data recorder or some form of nonvolatile memory.*

c. The display and sensor field-of-regard (FOR) should be sufficient for the intended operational conditions.

d. The sensor image may be presented on a display with or without primary flight data, such as attitude, heading, airspeed, radio/barometric altitude, lateral/vertical path deviations, flight path vector, and flight director commands.

e. If primary display information is presented in the form of symbology overlaying the image presentation, then the primary display information shall be scaled and aligned with the image presentation.

f. If primary flight and navigation information is displayed on an EVS display, it should meet the same integrity levels as the PFD information.

g. Criteria for the design, analysis, testing and installation of the HUD, including field-of-view, head motion box, and alignment, shall follow applicable guidance of SAE ARP 5288.

h. The EVS system installation and operations shall demonstrate that the criteria defined in §25.773, §23.773, §27.773, and §29.773, including validation that the display of EVS imagery does not conflict with the pilot compartment view, are met. The FAA may issue special conditions to achieve the intended level of safety in §25.773. The safety and performance of the pilot tasks associated with the use of the pilot compartment view shall not be degraded by the display of the EVS image. Pilot tasks which shall not be degraded by the EVS image include:

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

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

i. If applicable, SAE design standards for HUD or EFVS symbology, optical elements and video imagery are also prescribed with SAE AS 8055, SAE ARP 5288 and SAE ARP 5287. Specific design standards should be applied for resolution and line width, luminance and contrast ratio, chromaticity, and grayscale.

j. For HUD applications, the displayed field-of-regard (FOR) shall be conformal with the real world and appropriate for the system's intended function accounting for possible aircraft attitudes and wind effects.

k. The EVS design, regardless of the display type, should also consider the following requirements for display characteristics:

   1. Display characteristics listed in AC 25-11A are applicable to all aircraft.
   2. Undesirable display characteristics shall be minimized (e.g., blooming, “burlap”, running water, etc.).
   3. If EVS is implemented on a primary display, then the pilot's ability to see and use the required primary flight display information such as primary attitude, airspeed, altitude, command bars, etc. shall not be hindered or compromised by the EVS video.

2.1.2.2 SVS

Synthetic Vision Systems (SVS) require a terrain and obstacle database, a precision navigation position, and a display. The design and installation safety levels should be appropriate for the system’s intended function. The following guidance applies to SVS displays: FAA AC 23-26, FAA AC 25-11A, and FAA AC 23.1311-1B.

The following requirements apply to SVS installations:

a. The synthetic vision scene depiction shall be crew de-selectable. For an SVS image displayed on a HUD, a control shall be provided which permits the pilot flying to deactivate and reactivate the display of the SVS image on demand without removing the pilot’s hands from the primary flight controls (yoke or equivalent) and thrust control.

b. The display status of synthetic vision scene depiction, either through crew de-selection or as a result of a failure, shall be clearly indicated or obvious to the crew.

NOTE: *Consideration should be given to recording the SVS display status in a flight data recorder or some form of nonvolatile memory.*

c. The display may depict the scene from the pilot’s view looking through the front window or from outside the aircraft. If implemented on a primary display, then the display shall depict the scene from the pilot’s perspective looking through the front window.

d. Synthetic vision scene compression may result from FOR selections or display size limitations. Regardless, prominent topographical features shall be easily identified and correlated with the actual external scene. Also, the crew should be able to perceive relative distances to prominent topographical features. For example, the pilot should be able to identify an immediate terrain threat versus a distant terrain conflict.

e. Position accuracy, symbology, and topographical information should be consistent with each other.

f. Any aircraft incorporating SVS from the pilot’s perspective (ego-centric) shall also provide a TAWS or terrain warning system as defined in FAA AC 23-26 section 7.b. If terrain alerts and cautions are depicted on the SVS, they shall be consistent across all displays in the cockpit when terrain threats are identified.

g. The terrain and obstacle database, along with any other database used to create the SVS image shall be compliant to DO-200A as applicable.

h. A potential terrain or obstacle conflict shall be obvious to the crew. One mechanism for making such conflicts obvious on a primary display is an earth-based flight path vector.

i. Topographical features shall not intersect published approach paths.

j. The pilot’s view shall not be depicted below the earth’s surface.

k. The scene range from the eye position to the terrain horizon shall be sufficient so as to not be misleading and shall be appropriate to the intended function. One example of a scenario that this requirement is trying to prevent is misleading information due to a SVS range limitation to the horizon that could lead to crew confusion at a critical phase of flight. At some airports the missed approach can take the aircraft on a course towards mountains, but the mountains may be 40 miles from the final approach fix. Pilots need to see that the mountains will be a factor in their missed approach long before they get to the runway. Thus, it is not acceptable for an approach to look like it is in the plains until short final when the mountains in the distance finally start appearing on the PFD.

l. Water and sky depictions shall be clearly distinguishable.

m. The field-of-regard should be appropriate for the system's intended function and account for possible aircraft attitudes and wind effects.

n. Display characteristics shall comply with AC 23-26 and AC 25-11A, as applicable. For example, undesirable display characteristics shall be minimized (e.g., jitter, jerky motion, excessive delays, etc.).

o. If SVS is implemented on a primary display, then the pilot's ability to see and use the required primary flight display information such as primary attitude, airspeed, altitude, command bars, etc., shall not be hindered or compromised by the SVS.

p. SVS based primary displays shall 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 an appropriate recovery within one second. Information to perform effective manual recovery from unusual attitudes using chevrons, pointers, and/or permanent ground-sky horizon on all attitude indications is recommended. (See FAA AC 25-11A)

q. Due to curvature of the earth, distant terrain would not appear above the artificial horizon. Threatening terrain, close enough to generate a TAWS or terrain warning alert, should appear above the artificial horizon if it is higher than the aircraft altitude.

r. Dominant topographical features present in the SVS image should be identifiable in the outside view. The converse is also a requirement; dominant topographical features present in the outside view should be identifiable in the SVS image.

2.1.2.3 CVS

Combined Vision Systems (CVS) require a real-time imaging sensor and display that provides demonstrated vision performance for its intended function. They also require a terrain and obstacle database and a precision navigation position for the synthetic portion of the display. The design and installation safety levels should be appropriate for the system's intended function.

The following requirements apply to CVS installations:

a. Combined Vision Systems shall meet the combined requirements of the EVS and SVS implementations.

b. The EVS and SVS depictions shall be conformal with each other as required according to the intended function.

c. The mode (EVS, SVS, or CVS) should be displayed to the crew.

d. The blending of EVS and SVS images shall be such that there are no discrepancies significant enough to cause confusion to the flight crew. Image discrepancies between EVS and SVS that arise due to failure conditions shall be obvious to the crew.

2.2 EFVS

2.2.1 EFVS General Requirements

2.2.1.1 Enhanced Flight Vision Systems (EFVS) require a real-time imaging sensor providing:

(1) demonstrated vision performance in low visibility conditions, so the required visual references become visible in the image before they are visible naturally out-the-window, with,

(2) a level of safety suitable for the proposed operational procedure.

2.2.1.1.1 In the design of an EFVS, safety design goals are established for certification approval. The safety criteria for each phase of flight, including approach and landing systems are defined in terms of accuracy, continuity, availability and integrity. FAA and EASA design guidance provides that the overall safety requirement of the aircraft, in any mode of flight, is that any combination of failures that can cause an unsafe condition, including the probability of the crew to cope with the failures shall be fully assessed and categorized. The hazard level for any aircraft system, therefore, depends on the ability of the crew to cope with failures.

2.2.1.1.2 System failures which are not extremely improbable and produce effects with which the crew (or the aircraft itself) may not be able to safely cope, shall be mitigated. The aircraft systems shall be designed such that the entire fault probability is kept to an acceptable level, which is normally accomplished by redundancy and system monitoring.

2.2.1.1.3 The sensor image, combined with the required aircraft state and position reference symbology, is presented to the flight crew on the Head-Up Display (HUD) or other appropriate, equivalent display. For HUD 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.

2.2.1.1.4 The HUD and displayed field-of-regard (FOR) should be sufficient for the EFVS information to be displayed conformally over the range of anticipated aircraft attitudes, aircraft configurations, and environmental (e.g., wind) conditions. The aircraft state and position reference data is presented in the form of symbology overlaying the image presentation. The flight instrument data on the HUD are derived from existing aircraft systems to include:

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

2.2.1.1.5 The approach path situation information references and as appropriate, flight director guidance information should be based on the navaids dictated by the straight-in instrument approach procedure in use.

Under FAA regulations, as defined in §91.175, upon reaching the DA/DH or MDA/MDH, the required visual references presented in Table 3 shall be distinctly visible and identifiable to the pilot.

Under EASA regulations, as defined in EU-OPS Sub-Part E, upon reaching the DA/DH or MDA/MDH, the required visual references presented in Table 4 shall be distinctly visible and identifiable to the pilot.

2.2.1.2 EFVS System Performance - Standard Operation Conditions

2.2.1.2.1 In terms of sensor design requirements, the performance criteria can be quantified in terms of the range of the enhanced flight visibility, and the visual references of the runway environment that shall be seen by the sensor at operationally relevant distances.

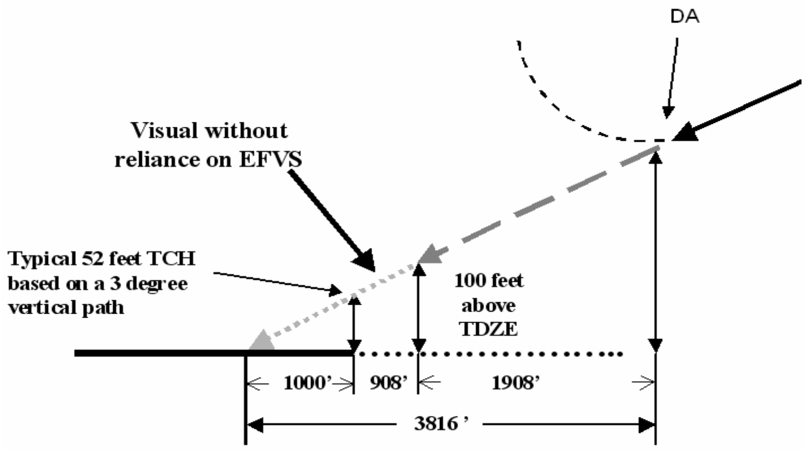


FIGURE 5: MINIMUM DETECTION RANGE

2.2.1.2.2 The minimum detection EFVS range (Figure 5 above) may be derived by using an assumed minimum distance of the aircraft at the nominal Category I (200 ft) decision altitude before which the EFVS shall image the runway threshold. On a 3 degree glideslope, the horizontal distance from the aircraft to the runway threshold is approximately 2816 feet (3816 feet from the precision touchdown zone markers). This range should be used as a minimum requirement. These values do not take into account pilot decision time or actual atmospheric conditions, or the use of non precision approaches which may require greater distances.

2.2.1.2.3 The EFVS operational requirement is further defined as meeting the detection and recognition criteria of the items defined by FAA §91.175(l). This regulation states the need for the pilot to see the required visual references at no lower than the Category I decision height. The necessary visual references, which are performance and design criteria, are presented in Table 3.

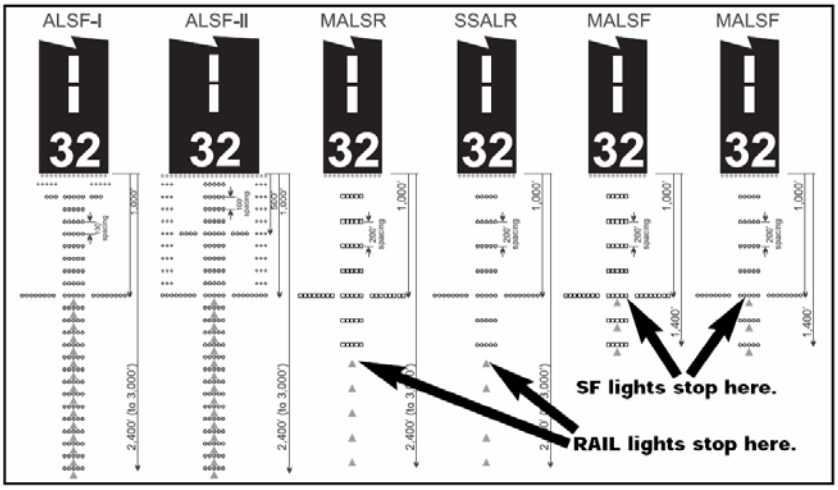
TABLE 3: 14 CFR §91.175 (L) OPERATING REQUIREMENTS

In order to operate an aircraft below DA/DH/MDA/MDH down to 100 feet height above TDZE, the following visual references for the intended runway shall be distinctly visible and identifiable to the pilot using the enhanced flight vision system: i. Approach light system, if installed; OR ii. visual references in BOTH paragraphs (l)(3)(ii)(A) and (B) -- (l)(3)(ii)(A) Runway threshold, identified by at least one of the following – -- beginning of the runway landing surface, -- threshold lights, or -- runway end identifier lights AND (l)(3)(ii)(B) Touchdown zone, identified by at least one of the following – -- runway touchdown zone landing surface, -- touchdown zone lights, -- touchdown zone markings, or -- runway lights.

TABLE 4: EU-OPS OPERATING REQUIREMENTS

A pilot may not continue an approach below MDA/MDH unless at least one of the following visual references for the intended runway is distinctly visible and identifiable to the pilot: Elements of the approach light system; The threshold; The threshold markings; The threshold lights; The threshold identification lights; The visual glide slope indicator; The touchdown zone or touchdown zone markings; The touchdown zone lights; Runway edge lights; **OR** Other visual references accepted by the Authority.

2.2.1.2.4 The visual references identified in Table 3 (FAA) or Table 4 (EASA requirements) need to be seen by the pilot flying via the EFVS at the specified distances required for non-precision and precision approaches. Design criteria should be developed using Figure 5 and Table 3 or Table 4 as the baseline. (Simulator modeling for approved and certified EFVS training programs also utilize the above criteria as source data for detection and resolution factors such runway size, surface material, light structures, taxi lights, etc.) The general arrangement and type of light structures, including dimensions and location with respect to the runway are shown in Figure 6.



(RAIL: Runway Alignment Indicator Lights; SF: Sequenced Flashing Lights)

(Calvert lighting system)

FIGURE 6: APPROACH LIGHT SYSTEM CONFIGURATIONS

2.2.2 EFVS System Requirements

2.2.2.1 The EFVS image shall be compatible with the field-of-view and head motion box of a HUD designed against SAE ARP 5288 ("Transport Category Head-Up Display (HUD) Systems"). The HUD and EFVS field-of-regard (FOR) shall provide a conformal image with the visual scene over the range of aircraft attitudes and wind conditions for each mode of operation.

2.2.2.2 EFVS display criteria shall meet the airworthiness certification requirements in 14 CFR §§21, 23, 25, 27, and 29 (as applicable). Specifically, the EFVS system installation and operations shall demonstrate compliance with the requirements listed below in Appendix B, EFVS FAR compliance checklist. These requirements are specific to EFVS and are in addition to all other requirements applicable to the HUD and the basic avionics installation.

2.2.2.3 The current FAA guidelines for Head-Up Displays apply with respect to EFVS. These criteria may include well established military as well as civil aviation standards for HUDs as defined in MIL-Handbook-1787C and AC 25-11A. SAE design standards for HUD symbology, optical elements and video imagery are also prescribed within SAE AS 8055, SAE ARP 5288 and SAE ARP 5287. Specific design standards should be applied for image size, resolution and line width, luminance and contrast ratio, chromaticity and grayscale.

2.2.2.4 The EFVS image, when superimposed on the HUD symbology and when used in combination with other airplane systems, shall be demonstrated to show that it meets the requirements below. The EFVS image and installation:

a) Shall be suitable for and successfully performs its intended function.

b) Shall allow the accurate identification and utilization of visual references, via both EFVS and natural vision as appropriate.

c) Shall not degrade safety of flight.

d) Shall not have unacceptable display characteristics

e) Shall have an effective control of EFVS display brightness without causing excessive pilot workload.

f) Shall have a readily accessible control to remove EFVS image from the HUD.

g) Shall not degrade the presentation of essential flight information on the HUD.

h) Shall not be misleading and shall not cause confusion or any significant increase in pilot workload.

i) Shall be sufficiently aligned and conformal to the external scene, including the effect of near distance parallax.

j) Shall not cause unacceptable interference with the safe and effective use of the pilot compartment view.

k) Shall not cause adverse physiological effects such as fatigue or eyestrain.

l) Shall not significantly alter the color perception of the external scene.

m) Shall allow the pilot to recognize misaligned or non-conformal conditions.

2.2.2.5 A HUD modified to display EFVS shall continue to meet the requirements of the original approval and demonstrated to be adequate for the intended function, in all phases of flight in which the EFVS can be used. 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 an appropriate recovery within one second. Information to perform effective manual recovery from unusual attitudes using chevrons, pointers, and/or permanent ground-sky horizon on all attitude indications is recommended. (See FAA AC 25-11A)

2.2.2.6 As outlined in 14 CFR §91.175, a flight path vector and flight path angle reference cue shall be displayed on the HUD (or equivalent display). The position of the flight path vector symbol shall correspond to the aircraft’s earth referenced flight path vector (within the stated performance accuracy of the HUD). The dynamic response of the flight path vector symbol shall not exhibit undue lag or overshoot due to pilot control inputs. The dynamic response requirements for the flight path vector symbology from SAE ARP 5589 should be followed.

CHAPTER 3

DETAILED SYSTEM REQUIREMENTS

3.1 EVS/SVS/CVS

3.1.1 EVS/SVS/CVS Detailed System Requirements

Based on the EVS (Figure 1) and SVS (Figure 2) block diagrams previously shown in this document, the EVS/SVS/CVS system architecture will contain the following elements:

3.1.1.1 EVS

The elements of an EVS are:

- EVS sensor as installed
- Sensor display processor
- Display
- System interface
- Aircraft interface
- Aircraft installation: sensor window, multispectral radome, or other installation as required
- Pilot interface

3.1.1.2 SVS

The elements of an SVS are

- Display
- System interface
- Aircraft interface
- Aircraft installation
- Terrain and obstacle database
- Position source
- Altitude source
- Pilot interface
- Attitude source
- Heading/track source

3.1.1.3 CVS

CVS consists of all elements of both EVS and SVS.

3.1.2 EVS/SVS/CVS Major Components

Integration of the major components includes the elements described in the preceding paragraph 3.1.1. The baseline minimum system is used in this document to define the subsystem minimum standards.

3.1.3 EVS/SVS/CVS Minimum System Performance

The following defines the subsystem minimum standards characteristics.

3.1.3.1 EVS

3.1.3.1.1 Image Characteristics

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

The image data shall be refreshed at 15 Hz or better.

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

3.1.3.2 SVS

3.1.3.2.1 Image Characteristics

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

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

The image shall be refreshed at 15 Hz or better and function smoothly during all expected maneuvering reasonable for the class and type of airplane.

The image latency for a Primary Flight Display or HUD shall be consistent with the image requirements of AC 25-11A. For other display in the flight deck a larger lag may be acceptable subject to the intended function.

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

3.1.3.2.2 Position Source

The position source shall be consistent with the intended function. The horizontal position source used for the SVS display should at least meet the criteria for TAWS installations as found in FAA AC 25-23 and AC 23-18. The horizontal position source should be consistent with that used for the onboard terrain awareness and alerting system on the aircraft and shall not provide contradictory indications of horizontal terrain clearance. Additional requirements for the horizontal position source may be necessary, depending on the intended functions of the SVS. HTAWS guidance is contained in AC 29-2C.

3.1.3.2.3 Altitude Source

The altitude source shall be consistent with the intended function. The altitude source used for the SVS display should at least meet the criteria for TAWS installations as found in FAA AC 25-23 and AC 23-18, including the need to account for cold weather operations. The altitude source should be consistent with that used for the onboard terrain awareness and alerting system on the aircraft and shall not provide contradictory indications of vertical terrain clearance. Additional requirements for the altitude source may be necessary, depending on the intended functions of the SVS. HTAWS guidance is contained in AC 29-2C.

3.1.3.2.4 Attitude Source

The attitude source shall be consistent with the intended function and not conflict with attitude information provided by the primary flight display.

3.1.3.2.5 Heading/Track Source

The heading/track source shall be consistent with the intended function and not conflict with heading/track information provided by the navigation display.

3.1.3.2.6 Terrain Database

The minimum terrain database resolution and accuracy shall be consistent with the intended function, and compliant with the resolution and accuracy listed in TSO-C151b, Appendix 1, section 6.3, or for helicopters, compliant with DO-309 “Minimum Operational Performance Standards (MOPS) for Helicopter Terrain Awareness and Warning System (HTAWS) Airborne Equipment.”

3.1.3.2.7 Obstacle Database

Synthetic vision databases shall include all available physical hazards greater than 200 feet above ground level, not just terrain. The system shall neither disregard nor corrupt obstacles available in the database greater than 200 feet above ground level. Obstacles displayed shall be those deemed hazardous to the phase of flight.

3.1.3.2.8 Navigation Database

The navigation database used by SVS for runway and airport information shall be consistent with that used by other systems in the airplane (e.g., Flight Management Systems).

3.1.3.3 CVS

The CVS shall meet the detailed performance requirements for EVS and SVS specified in sections 3.1.2.1 and 3.1.2.2 except where superseded by the following requirements.

Fusion of EVS and SVS shall require the images to be aligned within 5 milliradian (mrad) laterally and vertically at the boresight of the display.

3.1.4 EVS/SVS/CVS Aircraft Interface

3.1.4.1 EVS/SVS/CVS Pilot Controls

3.1.4.1.1 For display on a HUD, the minimum system shall include a control of EVS/SVS/CVS display contrast/brightness that is sufficiently effective in dynamically changing background (ambient) lighting conditions, to prevent distraction of the pilot, impairment of the pilot's ability to detect and identify visual references, masking of flight hazards, or otherwise degrade task performance or safety. If automatic control for image brightness is not provided, it shall be shown that manual setting of image brightness meets the above criteria and does not cause excessive workload.

3.1.4.1.2 The EVS/SVS/CVS display controls shall be visible to, and within reach of, the pilot flying from any normal seated position. The position and movement of the controls shall not lead to inadvertent operation. The EVS/SVS/CVS controls, except those located on the pilot's control wheel, shall be adequately illuminated for all normal background lighting conditions and shall not create any objectionable reflections on other flight instruments. Unless fixed illumination of the EVS/SVS/CVS controls is shown to be satisfactory under all lighting conditions for which approval is sought, there shall be a means to modulate it.

3.1.4.2 EVS/SVS/CVS Annunciations

3.1.4.2.1 Any modes of EVS/SVS/CVS operation shall be annunciated on the flight deck and visible to the crew. The modes of the EVS/SVS/CVS operation shall be made available to the flight data recorder as required.

3.1.5 EVS/SVS/CVS Display

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

3.1.6 EVS/SVS/CVS Preventive Maintenance Requirements

Approved manufacturer data will be used for preventive maintenance requirements.

3.1.7 EVS/SVS/CVS Built in Test (BIT)

A BIT capability shall be provided that, at a minimum, limits the exposure time to latent failures in support of the system safety assessment.

3.1.8 EVS/SVS/CVS System Safety Design Criteria

The overall safety requirement of the aircraft is based on installed equipment. To meet the safety criteria, the system design will be demonstrated through analysis and engineering tests to preclude failures that can cause hazardously misleading information to be presented to the pilot or crew, or which can otherwise subsequently cause an unsafe condition.

3.1.9 EVS/SVS/CVS Required Safety Level

In general, the sensor or system requirements and level of design shall be linked to the operational level proposed. Since this portion of the MASPS only addresses the no additional operational credit installations, the Hazard Levels detailed in Table 5 (Generic Functional Hazard Assessments) below for "Hazardously Misleading Information" (HMI) are assessed at a MAJOR level. One example of HMI would be the airplane level ramifications of a "frozen EVS/SVS/CVS display" that is undetected by the flight crew. This table represents a worst-case failure condition and it is anticipated that the applicant would enumerate the individual failure conditions that contribute to the overall classification.

A MAJOR FHA classification would typically equate to a ED-80/DO-254 and ED-12B/DO-178B Design Assurance Level "C" being assessed on the hardware and software respectively. Likewise, the DO-200A category for applicable databases would be Assurance Level 2.

TABLE 5: GENERIC FUNCTIONAL HAZARD ASSESSMENTS

FAILURE CONDITION	PHASE OF FLIGHT	FAILURE EFFECT on Airplane and/or Crew	HAZARD INDEX
LOSS OF FUNCTION			
Loss of EVS, SVS or CVS imagery on primary display, secondary display, or EFB	(Align with the System Operating Phases below)	Reduced crew strategic awareness of terrain, obstacles, and relevant cultural features	MINOR
MISLEADING INFORMATION			
Misleading EVS, SVS or CVS imagery on primary display	(Align with the System Operating Phases below)	Degraded crew strategic awareness of terrain, obstacles, and relevant cultural features leading to increased crew workload	MAJOR
Misleading EVS, SVS or CVS imagery on secondary display or EFB	(Align with the System Operating Phases below)	Degraded crew strategic awareness of terrain, obstacles, and relevant cultural features leading to increased crew workload	MAJOR

System Operating Phases

GROUND	TAKEOFF	IN-FLIGHT	LANDING
Taxi Maintenance	Takeoff Roll Prior to V1 Takeoff Roll After V1 Takeoff After VR to 200' Rejected Takeoff	Climb Gear Up Cruise Descent Gear Down Approach 200' to 0' Go Around	Touchdown & Rollout Taxi In

3.1.10 EVS/SVS/CVS Fail Safe Features

Any failure of the EVS/SVS/CVS shall not cause a failure of the interfaced equipment or associated systems. Likewise, any failure of interfaced equipment or associated systems shall not cause a failure of the EVS/SVS/CVS. This requirement shall be met through a system safety assessment and documented via Fault Tree Analysis (FTA), Failure Mode and Effects Analysis (FMEA), and Failure Mode and Effects Analysis Substantiation (FMEA Substantiation), or equivalent safety documentation. (Reference MIL-STD-1629A, SAE ARP4761, US Nuclear Regulatory Commission Fault Tree Handbook (NUREG-0492), and FAA AC 25.1309-1A.)

3.1.11 EVS/SVS/CVS Environmental Specifications

The EVS/SVS/CVS shall meet all specified operating requirements and shall provide required operating performance, life and reliability when operating within the aircraft and subsystem flight envelope as specified in EUROCAE ED-14F/RTCA DO-160F Environmental Conditions and Test Procedures for Airborne Equipment or future versions. These criteria shall also include the High-Intensity Radiated Fields (HIRF), Electromagnetic Interference (EMI) and Lightning requirements as specified in the certification basis of the aircraft to be installed.

3.2 EFVS

3.2.1 EFVS Detailed System Requirements

3.2.1.1 This section of the EFVS MASPS provides the specific minimum standard performance requirements for the EFVS.

3.2.1.2 The categories of EFVS sensors are Passive or Active (i.e., Electro Optic or Radar) sensors. The elements of an EFVS as defined in 14 CFR §91.175(m)(3) are:

- EFVS Sensor as Installed
- Sensor Display Processor
- Display
- System Interface
- Aircraft Interface
- Aircraft Installation: sensor window, multispectral radome, or other installation as required
- Pilot Interface

3.2.1.3 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.

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

3.2.1.5 Likewise, since the purpose of the EFVS sensor is to provide a visual advantage over the pilot's out-the-window view, the general performance analysis shall include the calculated transmission of electromagnetic energy in the visible spectrum and other frequencies that may assess length of transmission over a path with generalized extinction coefficients at a given wavelength. Examples of acceptable sensor models are MODTRAN and LOWTRAN which can be used to estimate the performance of infrared systems. Other models (FASCODE) for radar systems may be used for these types of sensors and provides a basic measure of signal attenuation helpful in assessing performance and viability for the functions defined in 14 CFR §91.175.

3.2.2 EFVS Major Components

Integration of the major components includes the installed sensor, its interconnections with the sensor display processor, the display device and pilot interface, and aircraft mechanical interface which can include the radome for the sensor. This baseline minimum system is used in this document to define the subsystem minimum standards.

3.2.3 EFVS Minimum System Performance

The following defines the subsystem minimum standards characteristics. Performance rationale is in Appendix D.

3.2.3.1 Latency

EFVS latency should be no greater than 100 milliseconds (msec). A longer lag time may be found satisfactory, provided it is demonstrated not to be misleading or confusing to the pilot.

3.2.3.2 EFVS Field of Regard (FOR)

The minimum fixed field of regard shall be 20 degrees horizontal and 15 degrees vertical. In applications where the FOR is centered on the Flight Path Vector the minimum vertical field of regard shall be 5 degrees. (± 2.5 degrees)

3.2.3.3 Off-Axis Rejection

A source in object space greater than 1 degree outside the field of view shall not result in any perceptible point or edge like image within the field of view.

3.2.3.4 Jitter

When viewed from the HUD eye reference point the displayed EFVS image jitter amplitude shall be less than 0.6 mrad. Jitter for this use is defined in SAE ARP 5288.

3.2.3.5 Flicker

Flicker is brightness variations at frequency above 0.25 HZ per SAE ARP 5288. The minimum standard for flicker shall meet the criteria of SAE ARP 5288.

3.2.3.6 Image Artifacts

The EFVS shall not exhibit any objectionable noise, local disturbances or an artifact that hazardously detracts from the use of the system (for example, burlapping, running water droplets, or internal system noise).

3.2.3.7 Image Conformality

The accuracy of the integrated EFVS and HUD image shall 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). Errors away from the bore sight shall be as defined in SAE ARP 5288.

3.2.3.8 Sensor/Sensor Processor

3.2.3.8.1 Dynamic Range

The minimum required dynamic range for passive EFVS shall be 48 db. For active EFVS, side lobes shall be 23 db below the main beam, and 40 db dynamic range plus Sensitivity Time Control (STC).

3.2.3.8.2 Sensor Image Calibration

Visible Image Calibrations and other built in tests that cannot be achieved within a total latency of 100 milliseconds shall 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 shall be removed from the pilot's display.

3.2.3.8.3 Sensor Resolution

The EFVS shall adequately resolve a 60 ft wide runway from 200 ft height above touchdown zone elevation with a typical 3-degree glide slope, referencing the required items in Table 3.

3.2.3.8.4 Passive Sensor Optical Distortion

Optical distortion shall be 5 percent or less across the minimal FOR as defined in Section 3.2.3.2 EFVS FOR and no greater than 8 percent outside the minimal FOR.

3.2.3.8.5 Sensor Sensitivity

The minimum required system performance for EFVS shall be such that the system is capable of meeting the system performance requirements in section 2.2.1.1. In this context, the EFVS sensor sensitivity shall be at least a Noise Equivalent Temperature Difference (NETD) of 50 mK, tested at an appropriate ambient temperature, for passive EFVS systems or -20dB sm/sm surface at Rmax from 200 ft height above touchdown zone elevation with a typical 3-degree glide slope for active EFVS systems. Passive sensors for different visible or short-wave infrared sources may require very sensitive detectors, as specified by low Noise Equivalent Powers.

3.2.3.8.6 Failure Messages

EFVS malfunctions detected by the system, and which may adversely affect the normal operation of the EFVS, shall be annunciated. As a minimum, specific in flight failure message(s) for sensor failure and frozen image shall be displayed to the flight crew.

3.2.3.8.7 Blooming

The sensor shall incorporate features to minimize objectionable blooming. Objectionable blooming is defined as the condition that obscures the required visual cues defined in Table 3 at 100ft height above touchdown zone elevation.

3.2.3.8.8 Image persistence

The image persistence time constant shall be less than 100 milliseconds. However burn in or longer image persistence caused by high energy sources shall be removed from the image to comply with Section 3.2.3.6 Image Artifacts, by a secondary on-demand process (e.g. the NUC process).

3.2.3.8.9 Dead Pixels

Dead pixels or sensor elements that are replaced by a “bad pixel” replacement algorithm shall be limited to 1 percent average of the total display area, with no cluster greater than 0.02 percent within the minimum field of regard.

3.2.4 EFVS Aircraft Interface

3.2.4.1 EFVS Pilot Controls

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

3.2.4.1.2 The EFVS display controls shall be visible to, and within reach of, the pilot flying from any normal seated position. The position and movement of the controls shall not lead to inadvertent operation. The EFVS controls, except those located on the pilot’s control wheel, shall be adequately illuminated for all normal background lighting conditions and shall not create any objectionable reflections on the HUD or other flight instruments. Unless fixed illumination of the EFVS controls is shown to be satisfactory under all lighting conditions for which approval is sought, there shall be a means to modulate it.

3.2.4.1.3 A readily accessible control shall be provided that permits the pilot to immediately deactivate or reactivate the display of the EFVS image on a HUD on demand without removing the pilot's hands from the primary flight controls (yoke or equivalent) and thrust control.

3.2.4.2 EFVS Annunciations

3.2.4.2.1 Any modes of EFVS operation shall be annunciated on the flight deck and visible to the crew. The modes of the EFVS operation shall be made available to the flight data recorder as required.

3.2.5 EFVS Display

3.2.5.1 Display Resolution of the HUD

The EFVS display shall adequately resolve a 60 ft wide runway from 200 ft height above touchdown zone elevation with a typical 3-degree glide slope. The pilot needs to be able to detect and accurately identify the visual references in the image.

3.2.5.2 Imagery and Symbology Display

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

3.2.5.3 Co-Pilot Repeater Display (European Regulations)

Under EASA Regulations, the repeater on the Co-Pilot (PNF) side may be in a second HUD or in a head down display (HDD). The HDD may be shown on a multi-function display (MFD) window of the avionics suite or on the flight management system control display unit or on a separate unit. The image quality of the repeater display shall be equivalent or better than the EFVS HUD image and conform to the requirements described in EASA Technical Guidance Leaflet (TGL)-42, paragraph 1.7. If repeater display is the PFD, then EVS imagery shall not interfere with primary flight information and shall be evaluated accordingly.

3.2.6 EFVS Preventive Maintenance Requirements

Approved manufacturer data will be used for preventive maintenance requirements.

3.2.7 EFVS Built in Test (BIT)

A BIT capability shall be provided that, at a minimum, limits the exposure time to latent failures in support of the system safety assessment.

3.2.8 EFVS System Safety Design Criteria

3.2.8.1 The EFVS system shall be shown to perform its intended function for each operation and phase of flight that it would be used. The normal operation of the EFVS cannot adversely affect, or be adversely affected by other airplane systems. Detected malfunctions of the EFVS system shall be annunciated and the malfunctioning display elements should be removed. The display of misleading EFVS information, in particular of information that provides attitude, altitude and distance cues such as outside terrain imagery, shall be addressed in the system safety assessment.

3.2.8.2 The criticality of the EFVS system's function to display imagery, including the potential to display misleading information, shall be assessed according to 14 CFR §23/25/27/29.1309, AC 25-11A (chapter 4), and AC 25.1309-1A, AC 23.1311-1B and AC 23.1309-1C as appropriate All alleviating flight crew actions that are considered in the EFVS safety analysis shall be validated during testing either for incorporation in the AFM limitation section, procedures section or for inclusion in type-specific training.

3.2.9 EFVS Required Safety Level

3.2.9.1 The applicant shall be required to demonstrate a satisfactory safety (failure and performance) level which shall not be less than the safety level required for non-EVS based precision and non-precision approaches with decision altitudes of 200 ft or above. In showing compliance with these safety requirements, probabilities may not be factored by the portion of approaches which are made using EFVS. Consideration, however, may be given to the EFVS critical flight time, i.e. from the highest DH that may be expected for an EFVS based approach to 100 ft above the TDZE.

3.2.9.2 The required Design Assurance Levels (DALs) are directly linked to the specific intended use and to the specific EFVS installation as an integrated part of the cockpit flight information system.

3.2.9.3 There are failure modes within the EFVS which determine that software and hardware DALs shall be EUROCAE ED-12B/RTCA DO-178B level C (major) as a minimum. However, dependent upon the mitigations utilized by the applicant stemming from the specific EFVS and cockpit installations, the DALs required may be higher than this minimum level.

3.2.9.4 The airplane level Functional Hazard Analysis (FHA) to be prepared by the applicant shall determine whether the minimum required DALs of level C are adequate for the applicant's specific installation.

3.2.9.5 A System Safety Analysis (SSA) of an EFVS was performed for a certification on an instrument flight capable airplane for straight-in non-precision and precision approach and landing operation per 14 CFR §91.175(l) and (m). This SSA is shown in Appendix C, table C.3 for example and general guidance only. An applicant shall provide the applicable FAR/CS23/25/27/29.1309 analysis.

3.2.9.6 A safety analysis shall be conducted to show that the EFVS, as defined in paragraph 1.3.1.3 meets all the integrity requirements for the airplane, HUD and EFVS. System and subsystem malfunctions which are not shown to be extremely improbable shall be demonstrated as appropriate in a simulation or in flight. The malfunction annunciation and fault detection schemes shall satisfy the required level of safety.

3.2.10 EFVS Fail Safe Features

Any failure of the EFVS shall not cause a failure of the interfaced equipment or associated systems. Likewise, any failure of interfaced equipment or associated systems shall not cause a failure of the EFVS. This requirement shall be met through a system safety assessment and documented via Fault Tree Analysis (FTA), Failure Mode and Effects Analysis (FMEA), and Failure Mode and Effects Analysis Substantiation (FMEA Substantiation), or equivalent safety documentation. (Reference MIL-STD-1629A, SAE ARP4761, NUREG-0492, and FAA AC 25.1309-1A.)

3.2.11 EFVS Environmental Specifications

The EFVS shall meet all specified operating requirements and shall provide required operating performance, life and reliability when operating within the aircraft and subsystem flight envelope as specified in EUROCAE ED-14F/RTCA DO-160F Environmental Conditions and Test Procedures for Airborne Equipment or future versions. These criteria shall also include the HIRF, EMI and Lightning requirements as specified in the certification basis of the aircraft to be installed.

CHAPTER 4

PERFORMANCE EVALUATION

4.1 EVS/SVS/CVS/EFVS PERFORMANCE DEMONSTRATION

The performance demonstration, establishing aircraft system compliance with applicable FAA and EASA regulations, will require bench testing, flight testing, data collection, and data reduction to show that the proposed performance criteria can be met. Minimal performance standards require an evaluation of the system used during anticipated operational scenarios. The performance evaluations should therefore include demonstrations of taxi, take-off, approach, missed approaches, failure conditions, cross wind conditions, and approaches into specific airports as appropriate for the system's intended function.

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

There are four general verification methods to be used. (Reference FAA AC 25.1329-1B and EASA AMC 25.1329) These are:

- Analysis - compliance to the requirement is demonstrated via an engineering analysis
- Flight Test – compliance to the requirement is demonstrated on an appropriate aircraft (in the air, or on the ground)
- Laboratory Test – compliance to the requirement is demonstrated on an engineering bench representative of the final EVS/SVS/CVS/EFVS system being certified
- Simulation – compliance to the requirement is demonstrated in a flight simulator

The applicant shall enumerate the individual verification methods that comprise the overall verification activity in a certification plan that will be agreed with the applicant's certification authority.

For extensions, features, and design decisions not explicitly specified in the MASPS, human factors evaluation shall be conducted. This evaluation may be conducted through bench, simulation or flight testing.

Verification is required that both the installed system and the individual system components meet the general requirements described in Section 2 and the sub-system specific requirements described in Section 3.

Demonstration of the section 2 general requirements shall be by flight test and other appropriate means, which may include use of a flight simulator. An example of a flight test program that would satisfy these minimum requirements for EFVS is described in Appendix F. The flight test program assumes that the guidance system utilized to satisfactorily position the airplane at the DH has been separately tested and shown to fully perform its intended function. Testing and data collection to demonstrate this is not part of this document.

Airframe and equipment manufacturer based tests or analysis as applicable shall be developed and conducted to validate the system requirements detailed in Section 3. No specific test procedures are cited, as it is recognized that alternative methods may be used. Alternate procedures may be used if it can be demonstrated that they provide all the required information. System performance tests as they relate to operational capability are the most important tests. Subsystem tests are used as subsystems are added during system buildup to ensure appropriate subsystem performance as it relates to overall system performance.

Minimal performance standards require an evaluation of the system used during anticipated operational scenarios.

4.2 ENVIRONMENTAL QUALIFICATION

Installed equipment using this MASPS should meet EUROCAE ED-14F/RTCA DO-160F.

4.3 DESIGN ASSURANCE

Software design assurance tests shall be conducted per the requirements of EUROCAE ED-12B/RTCA DO-178B "Software Considerations in Airborne Systems and Equipment Certification". The issue shall be current at time of application.

Hardware design assurance tests shall be conducted per the requirements of EUROCAE ED-80/RTCA DO-254 "Design Assurance Guideline for Airborne Electronic Hardware" if applicable. The issue shall be current at time of application.

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Frank Maciolek		Bundeswehr Technical and Airworthiness Center for Aircraft (wtd 61)
John Malley		Predesa, LLC
Chris Martin		Bombardier Aerospace
Roman Marushko		Transport Canada
Clement Mathieu		Dassault Aviation
Sean McCourt		FLIGHT DECK RESOURCES
Fraser McGibbon		BAE SYSTEMS
John McKinley		University Research Foundation
Bradford Miller		Federal Aviation Administration
Dennis Mills		Federal Aviation Administration
Harold Moses		RTCA, Inc.
Anand Mundra		MITRE Corporation/CAASD
Terry Neale		UK - Civil Aviation Authority
Dutch Neilson		Sierra Nevada Corporation
Richard Newman		Federal Aviation Administration
Ndubuisi Nnorom		Federal Aviation Administration
Christian Nouvel		Thales Avionics, Inc. - Aerospace Division
Mirth Oomens		Universal Avionics Systems Corp.
Dennis Overman		Federal Aviation Administration
Tom Phan		Federal Aviation Administration
Jack Pinto		Federal Aviation Administration
Sandra Poussin		Airbus France
David Prescott	WG 1 Chair	Honeywell International, Inc.
Ricardo Price		Chelton Flight Systems
Charles Rogers		Cessna Aircraft Company
Rudolph Ruana		RTCA, Inc.
Dean Rudy		Sierra Nevada Corporation
Wes Ryan		Federal Aviation Administration
Julian Sanchez		MITRE Corporation/CAASD
Greg Saylor		Air Line Pilots Association, International
Mark Schlegel		Cessna Aircraft Company
Gu Shimin		CARERI
Ernie Skiver		Federal Aviation Administration
Leslie Smith		Federal Aviation Administration
Michael Snow		The Boeing Company
Robert Speijer		CMC Electronics an Esterline Company
Cary Spitzer		AvioniCon
Terry Stubblefield		Federal Aviation Administration
Paul Swearingen		Rockwell Collins, Inc.
Thomas Tekach		SAIC
Stephen Thompson		NETJETS, Inc.
Carlo Tiana		Aireyes, Inc.
Julio Ueno		EMBRAER
Alper Ulku		ASELSAN, Inc.
Frans van Gorkum		European Aviation Safety Agency
Mike Veilleux		Kollsman, Inc.

James Verbeke		Jeppesen
Christoph Vernaleken		EADS - Military Air Systems
Lou Volchansky	Designated Federal Official	Federal Aviation Administration
Lawson Wade		Avidyne Corporation
Matt Wagner		Sierra Nevada Corporation
Cheng Wang		Universal Avionics Systems Corp.
James Ward		Gulfstream Aerospace Corporation
Scott Williams		MITRE Corporation/CAASD
Sandy Wyatt		Honeywell International, Inc.
Dror Yahav		Elbit Systems Ltd.
Steve Young		National Aeronautics & Space Administration
Ken Zimmerman		Rockwell Collins, Inc.
Greg Zuro		Max-Viz, Inc.

APPENDIX A

ACRONYMS AND DEFINITIONS

Appliance [§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.

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 Sequenced Flashing 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)

APV (EU OPS)

An APV operation is an instrument approach which utilizes lateral and vertical guidance, but does not meet the requirements established for precision approach and landing operations, with a DH not lower than 250 ft and a runway visual range of not less than 600m unless approved by the Authority.

Combined Vision System (CVS)

A system which combines information from an Enhanced Vision System and a Synthetic Vision System in a single integrated display.

Command Guidance

Symbolic information that directs the pilot to follow a course of action to control attitude or thrust in a specific situation (e.g., Flight Director).

Conformal

(AC 25-11A) Refers to displayed graphic information that is aligned and scaled with the outside view.

Decision altitude [§1.1]

Decision altitude (DA) is a specified altitude in an instrument approach procedure at which the pilot shall 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.

Decision height [§1.1]

Decision height (DH) is a specified height above the ground in an instrument approach procedure at which the pilot shall 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.

Ego-centric

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

Enhanced Flight Visibility (EFV) [§1.1]

The average forward horizontal distance, from the cockpit of an aircraft in flight, at which prominent topographical objects may be clearly distinguished and identified by day or night by a pilot using an enhanced flight vision system.

Enhanced Flight Vision System (EFVS) [§1.1 and §91.175(m)]

An installed airborne system which uses an electronic means to provide a display of the forward external scene topography (the applicable natural or manmade features of a place or region especially in a way to show their relative positions and elevation) through the use of imaging sensors, such as forward looking infrared, millimeter wave radiometry, millimeter wave radar, and/or low light level image intensifying. The EFVS imagery is displayed along with the additional flight information and aircraft flight symbology required by 14 CFR 91.175 (m) on a head-up display, or an equivalent display, in the same scale and alignment as the external view and includes the display element, sensors, computers and power supplies, indications, and controls.

Enhanced Vision System (EVS)

An electronic means to provide a display of the forward external scene topography (the natural or manmade features of a place or region especially in a way to show their relative positions and elevation) through the use of imaging sensors, such as a forward looking infrared, millimeter wave radiometry, millimeter wave radar, low light level image intensifying. JAA/EASA uses term “EVS” as equivalent to FAA description of “EFVS”.

NOTE: *Unlike an EFVS, an EVS does not necessarily provide the additional flight information/symbology required by 14 CFR 91.175(m), may not use a head-up display or an equivalent display, and may not be able to present the image and flight symbology in the same scale and alignment as the outside view. This system can provide situation awareness to the pilot, but does not meet the regulatory requirements of 14 CFR 91.175(m). As such, an EVS cannot be used as a means to determine enhanced flight visibility or to identify the required visual references and descend below the minimum descent altitude (MDA) or decision height (DH).*

Enhanced Vision System (EU OPS)

An electronic means of displaying a real-time image of the external scene through the use of imaging sensors.

Equivalent display

In the context of §91.175(m), a display which has at least the following characteristics:

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

Exo-centric

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.

Eye Reference Point (ERP)

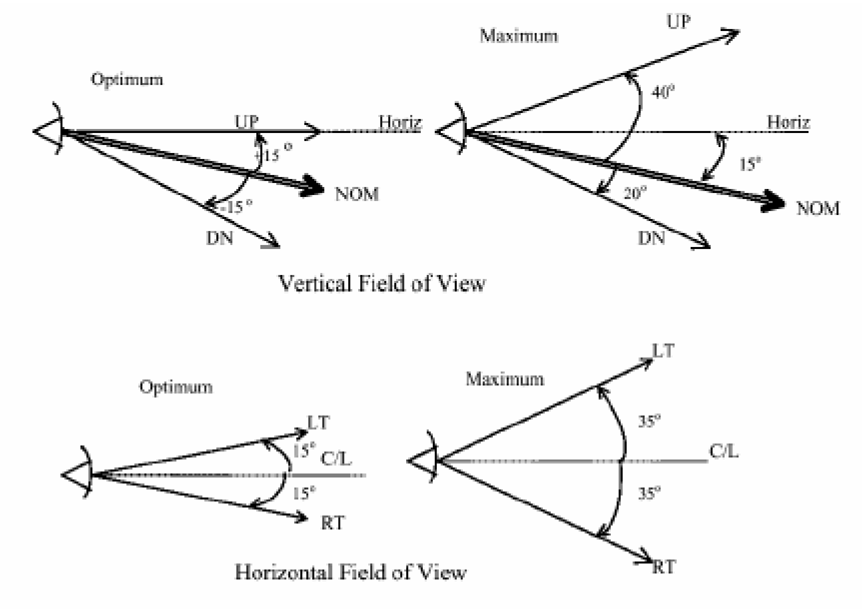
The ERP is the point in the cockpit that allows for a finite reference enabling the precise determination of geometric entities that define the layout of the cockpit and displays.

Field of Regard (FOR) (SAE ARP 5677)

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

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. FAA AC 25-11A provides the following diagram for primary field of view.



Flight Path Angle Reference Cue

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

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.

Flight Visibility [§1.1]

The average forward horizontal distance, from the cockpit of an aircraft in flight, at which prominent unlighted objects may be seen and identified by day and prominent lighted objects may be seen and identified by night.

Head Up Display (HUD) (AC 25.1329-1B)

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

IFR conditions [§1.1]

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

Instrument [§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.

Minimum descent altitude [§1.1]

The lowest altitude, expressed in feet above mean sea level, to which descent is authorized on final approach or during circle-to-land maneuvering in execution of a standard instrument approach procedure, where no electronic glide slope is provided.

Noise Equivalent Power (NEP)

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

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.

Non-Uniformity Correction (NUC)

Calibration of a detector utilizing more than one detector element.

Precision approach procedure [§1.1]

A standard instrument approach procedure in which a precision lateral and vertical path is provided.

Primary Flight Display (PFD)

The displays used to present primary flight information.

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.

Synthetic Vision [§1.1]

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

Synthetic Vision System (SVS) (AC 25.1329-1B)

An electronic means to display a computer-generated image of the applicable external topography from the perspective of the flight deck that is derived from aircraft attitude, altitude, position, and a coordinate-referenced database.

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

Visual References

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

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APPENDIX B

TECHNICAL REFERENCES

Latest versions of these references should be referenced as available.

SAE Publications

ARP 4101	Core Document, Flight Deck Layout and Facilities
ARP 4102	Core Document, Flight Deck Panels, Controls and Displays
ARP 4103	Flight Deck Lighting and Visual Interface
ARP 4105	Nomenclature and Abbreviations for Use on the Flight Deck
ARP 4754	Certification Considerations for Highly-Integrated Or Complex Aircraft Systems
ARP 4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
ARP 5288	Transport Category Airplane Head Up Display (HUD) Systems
ARP 5677	Human Engineering Considerations for Cockpit Integration of Enhanced/Synthetic Vision Systems
AS 5703	Minimum Performance Standard for Enhanced Vision System

US Government Publications

MIL-HDBK – 87213 Military Handbook: Electrically/Optically Generated Airborne Displays

MIL-HDBK – 217 Reliability Prediction of Electronic Equipment

RTCA DO/ EUROCAE ED Publications

DO-160F/ED-14F	Environmental Conditions and Test Procedures for Airborne Equipment
DO-178B/ED-12B	Software Considerations in Airborne Systems and Equipment Certification
DO-200A/ED-76	Standards for Processing Aeronautical Data
DO-254/ED-80	Design Assurance Guidance for Airborne Electronic Hardware
DO-276A/ED-98A	User Requirements for Terrain and Obstacle Data
DO-309	Minimum Operational Performance Standards (MOPS) for Helicopter Terrain Awareness and Warning System (HTAWS) Airborne Equipment

FAA Publications and Documents

Key Regulations

14 CFR §91.175 Takeoff and Landing under IFR

14 CFR §121.651 Takeoff and Landing weather minimums: IFR: All certificate holders

14 CFR §125.381 Takeoff and Landing weather minimums: IFR

14 CFR §135.225 IFR: Takeoff, approach and landing minimums

FAA Orders

FAA Order 6750.24E Instrument Landing System and Ancillary Electronic Component Configuration and Performance Requirements

FAA Order 8400.13C Procedures for the Approval of Special Authorization Category II and Lowest Standard Category I Operations

FAA Advisory Circulars (AC)

AC 91-16 Category II Operations General Aviation Airplanes

AC 120-28D Criteria for Approval of Category III Weather Minima for Takeoff, Landing, and Rollout

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

AC 23-26 Synthetic Vision and Pathway Depictions on the Primary Flight Display

AC 23.1309-1C Equipment, Systems, and Installations in Part 23 Airplanes

AC 23-1311-1B Installation of Electronic Display Instrument Systems in Part 23 Airplanes

AC 25-11A Electronic Flight Deck Displays

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

AC 25-1301A Aircraft Instrument Installation and Operations

AC 25-1309-1A System Design and Analysis

AC 25.1329-1B Approval of Flight Guidance Systems

AC 25.1523-1 Minimum Flight Crew

AC 29-2C Certification of Transport Category Rotorcraft

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

AC 120-57A Surface Movement Guidance and Control System

FAA HUD Certification Working Paper PS-ANM100-2001-0085

FAA EFVS FAR Compliance

14 CFR §	Description	Acceptable Method of Compliance
23/25/27/29.1	Applicability	
23/25/27/29.251	Vibration and Buffeting	Flight Test
23/25/27/29.301	Loads	Analysis
23/25/27/29.303	Factor of safety	Analysis
23/25/27/29.307	Proof of structure	Analysis
25/27/29/.571 23.573	Damage-tolerance	Analysis
25.581	Lightning Protection	Analysis
23/25/27/29.601	General	Drawing
23/25/27/29.603	Materials	Drawing
23/25/27/29.605	Fabrication methods	Drawing
23/25/27/29.609	Protection of structure	Drawing
23/25/27/29.611	Accessibility provisions	Drawing
23/25/27/29.619	Special factors	Analysis
23/25/27/29.625	Fitting Factors	Analysis
25.631	Bird Strike Damage	Data
23/25/27/29.771	Pilot compartment	Flight Test
23/25/27/29.773	Pilot compartment view	Flight Test

23/25/27/29.777	Cockpit controls	Flight Test
23/25/27/29.1301	Function and installation	Flight Test
23/25/27/29.1309	Equip, systems, and install	Analysis/Data
25.1316	System lightning protection	Test
23/25/27/29.1321	Arrangement and visibility	Flight Test
23/25/27/29.1322	Warning, caution, advisory lights	Flight Test
25.1353	Electrical equipment and installation	Analysis
23/25/27/29.1357	Circuit protective devices	Analysis/Ground Test
23/25/27/29.1381	Instrument lights	Flight Test
23/25/27/29.1419	Ice Protection	Analysis
23/25/29.1431(a)(c)	Electronic equipment	Analysis
23/25/27/29.1459(e)	Flight data recorders	Flight test
23/25/27/29.1501	General (operating limitations)	Flight Test
23/25/27/29.1525	Kind of Operation	Flight Test
23/25/27/29.1529	Instr. for Continued Airworthiness	Data
23/25/27/29.1581	Airplane flight manual	Data/Flight Test
23/25/27/29.1583	Operating limitations	Data/Flight Test
23/25/27/29.1585	Operating procedures	Data/Flight Test

14 CFR Part 23/EASA CS 23 - Airworthiness Standards: Normal, Utility, Acrobatic, And Commuter Category Airplanes

14 CFR Part 25/EASA CS 25 - Airworthiness Standards: Transport Category Airplanes

Additional Guidance

§25.1323 Airspeed indicating systems Flight Test

§25.1335 Flight director systems Flight Test

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APPENDIX C

SYSTEM SAFETY REQUIREMENTS LOGIC

C.1 Safety criteria for approach and landing systems generally consider four elements: accuracy, continuity, availability and integrity. These criteria apply to both the external navigation systems as well as airborne navigation equipment. Trajectory management or flight technical error, which can be interpreted as signal structure that contributes to roughness, bends and scalloping of ILS-based guidance, shall also be considered. They also define how the airspace and aircraft are integrated together to make a safe approach and landing. The FAA has developed, in conjunction with the other governments definitions related to safety and performance for a landing system.

C.2 For Part 25 aircraft, 14 CFR §25.1309 and AC 25.1309 define the safety requirements for any aircraft systems, and the means for verifying that they are met. The overall safety requirement of the aircraft, in any mode of flight, is that any combination of failures that can cause an unsafe condition, including the probability of the crew to cope with the failures, shall be less than 10 -9 per flight segment. That number has been accepted by the FAA to assure a negligible adverse effect on accident rates, and in fact to help reduce them as new systems come on line.

C.3 For Part 23 aircraft, similar information can be found in 14 CFR §23.1309 and FAA AC 23.1309. The relationship among airplane classes, probabilities, severity of failure conditions and software development assurance levels is found in FAAAC 23.1309-1C.

C.4 The required level of safety for any aircraft systems, therefore, depends on the ability of the crew to cope with failures as shown in the appropriate table below which lists the categories of systems and failure probabilities to meet the safety requirements in Part 25 and Part 23 aircraft.

TABLE C-1: REQUIRED LEVEL OF SAFETY, PART 25 AIRCRAFT

Required Level Of Safety, Part 25 aircraft		
Classification	*Effect*	*Target Probability P*
Minor	Slight reduction in safety margins or functional capabilities. Slight increase in crew workload. Some inconvenience to occupants.	1E-3 > P > 1E-5
Major	Significant reduction in safety margins or functional capabilities. Significant increase in crew workload or in conditions impairing crew efficiency. Some discomfort to occupants.	1E-5 > P > 1E-7
Severe Major	Large reduction in safety margins or functional capabilities. Higher workload or physical distress such that the crew could not be relied upon to perform tasks accurately or completely. Adverse effects upon occupants including serious or fatal injury to a relatively small number of occupants other than the flight crew.	1E-7 > P > 1E-9
Catastrophic	Failure conditions which would prevent continued safe flight and landing, resulting in multiple fatalities, usually with the loss of the airplane.	1E-9 > P

C.5 To meet the safety criteria, the EFVS design will be demonstrated through analysis and engineering tests to preclude any critical failure combinations that can cause hazardously misleading information to be presented to the crew, or which can otherwise subsequently cause an unsafe condition. Failures which are self-evident or made obvious to the crew, and with which they can safely cope, need not be specifically monitored.

C.6 The aircraft state data is provided by the standard inertial, air data, and radio guidance sensors that all instrument flight equipped aircraft contain. The HUD or display processor will be required to be at a sufficient level of safety for the aircraft type and application to detect critical random, or common, faults that could otherwise cause an unsafe condition. The ability to continue the approach below the standard Category I DA/DH/MDA/MDH therefore is strictly borne by the pilot, a safety factor already accounted for in the safety analysis for standard Category I operations. The example below is a model case and cannot be applied for any specific aircraft. Functional Hazard Assessments as required by the FAA are aircraft and systems specific.

TABLE C-2: EXAMPLE EFVS/HUD FUNCTIONAL HAZARD ASSESSMENT, PART 25 AIRCRAFT, ILS APPROACHES TO 100 FT HEIGHT ABOVE TOUCHDOWN, RVR 1200 FT

FHA NO.	FAILURE CONDITION	PHASE OF FLIGHT	FAILURE EFFECT	HAZARD INDEX	OBJECTIVE
1.0	LOSS OF FUNCTION				
1.1	Loss of EFVS imagery on HUD	Taxi and Takeoff Enroute Terminal Arrival Final Approach - Above 100 ft. EFVS height above touchdown zone elevation Go-Around	Crew would revert to standard head-up and/or head down procedures	MINOR	1E-03
1.2	Loss of EFVS imagery on HUD	Final Approach - From 100 ft. height above touchdown zone elevation to Landing	Crew performs a go-around or possibly a minimum flare landing	MINOR	1E-03
1.3	Loss of HUD symbology	Taxi and Takeoff Enroute Terminal Arrival Final Approach - Above 100 ft. height above touchdown zone elevation Go-Around	Crew would revert to standard head down procedures	MINOR	1E-03

FHA NO.	FAILURE CONDITION	PHASE OF FLIGHT	FAILURE EFFECT	HAZARD INDEX	OBJECTIVE
1.4	Loss of HUD symbology	Final Approach - From 100 ft. height above touchdown zone elevation to Landing	Pilot would continue the approach and land	MINOR	1E-03
1.5	Loss of HUD and EFVS Imagery	Final Approach - From 100 ft. height above touchdown zone elevation to Landing	Pilot would continue the approach and land	MINOR	1E-03
2.0	MISLEADING INFORMATION				
2.1	Misleading EFVS imagery on HUD	Taxi Enroute Terminal Arrival Final Approach - Above 100 ft height above touchdown zone elevation Go-Around	Crew would revert to standard head down procedures	MINOR	1E-03
2.2	Misleading EFVS imagery on HUD	Final Approach - From 100 ft. height above touchdown zone elevation to Landing	Crew performs a go-around or possibly a minimum flare landing	MAJOR	1E-05
2.3	Misleading HUD symbology	Taxi and Takeoff Enroute Terminal Arrival Final Approach - Above 100 ft. height above touchdown zone elevation Final Approach - From 100 ft. height above touchdown zone elevation to Landing Go-Around	Pilot would take appropriate action as defined in by AFM for standard displays and HUD	Various failure conditions with the highest hazard index being MAJOR	Various failure conditions with the highest objective being 1E-05
2.4	Misleading EFVS imagery and HUD symbology	Final Approach - Above 100 ft. height above touchdown zone elevation	Copilot should recognize condition using copilot's PFD	MAJOR	1E-05
2.5	Misleading EFVS imagery and HUD symbology	Final Approach - From 100 ft. height above touchdown zone elevation to Landing	Crew performs a go-around or possibly a minimum flare landing	MAJOR	1E-05
3.0	OBSTRUCTION OF PILOT'S VIEW				
3.1	Obstruction of the pilot's view through the HUD	Takeoff	Pilot would abort takeoff prior to V1	MAJOR	1E-05
3.2	Obstruction of the pilot's view through the HUD	Taxi Enroute Terminal Arrival	Pilot would take appropriate action	MINOR	1E-03
3.3	Obstruction of the pilot's view through the HUD	Final Approach - Above 100 ft. height above touchdown zone elevation Go-Around	Pilot would take appropriate action	MAJOR	1E-05
3.4	Obstruction of the pilot's view through the HUD	Final Approach - From 100 ft. height above touchdown zone elevation to Landing	Pilot would execute a go-around	MAJOR	1E-05

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APPENDIX D

EFVS MINIMUM SYSTEM PERFORMANCE STANDARD RATIONALE

Section 3.2 of this document presents minimum performance standards for an EFVS and associated subsystem/functions that constitute required elements of minimum system performance. In the following, the rationale for these minimum performance standards elements is presented.

D.1 SYSTEM REQUIREMENTS RATIONALE

D.1.1 **Latency** (Ref 3.2.3.1)

D.1.1.1 Requirement: EFVS latency should be no greater than 100 msec. A longer lag time may be found satisfactory, provided it is demonstrated not to be misleading or confusing to the pilot.

D.1.1.2 Rationale: EFVS latency causes, at best, undesirable oscillatory image motion in response to pilot control inputs or turbulence. At worst, EFVS latency may cause pilot-induced oscillations if the pilot attempts to use the EFVS for active control during precision tracking tasks or maneuvers in the absence of other visual cues.

D.1.1.3 Latency, as a general requirement, should not be discernable to the pilot and should not affect control performance or increase pilot workload. Latency requirements depend upon whether the information is used for situational information only or if these data provide visual guidance or command information. For this reason, longer lag times may be found satisfactory, provided suitable demonstration.

D.1.1.4 A maximum acceptable latency of 100 msec was established using similarity arguments from SAE ARP5288 and other accepted industry standards such as MIL-HNDBK-1797.

D.1.2 **EFVS Field of Regard (FOR)** (Ref 3.2.3.2)

D.1.2.1 Requirement: The minimum fixed field of regard shall be 20 degrees horizontal and 15 degrees vertical. In applications where the FOR is centered on the Flight Path Vector the minimum vertical field of regard shall be 5 degrees. (± 2.5 degrees)

D.1.2.2 Rationale: The requirement for a 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 field-of-regard portrayed on the HUD is established by three primary determinants:

a. the HUD and EFVS sensor Field-Of-View;

b. the orientation of the HUD with respect to the aircraft frame of reference (e.g., boresight); and,

c. the orientation (e.g., attitude) of the aircraft.

D.1.2.3 Under the general requirements of Section 2, the EFVS imagery shall be conformally drawn. The EFVS is presented, however, using an approved HUD installation which presumably followed other certification requirements such as the recommendations of SAE ARP 5288. As stipulated in SAE ARP-5288, "the design of the HUD installation should provide adequate display fields-of-view in order for the HUD to function correctly in all anticipated flight attitudes, aircraft configurations, or environmental conditions such as crosswinds for which it is approved. Limitations should be clearly specified in the AFM if the HUD can not be used throughout the full aircraft flight envelope."

D.1.2.4 Nonetheless, a quantitative EFVS FOR requirement was established herein as a minimum design criteria which is to be checked qualitatively during certification flight test for sufficiency in meeting its intended function. After considering the minimum field of regard requirements for various aircraft attitudes and wind conditions using a critical altitude of 200 ft height above touchdown zone elevation for EFVS visibility, a simple requirement of 20 degrees horizontal and 15 degrees vertical emerged.

D.1.2.5 A variable FOR was permissible assuming a slewable sensor (i.e., variable field-of-regard), centered on the Flight Path Vector, with +/- 2.5 deg about the Flight Path Vector to allow for momentary flight path perturbations and to allow sufficient fore/aft view of the required visual references.

D.1.3 **Off-Axis Rejection** (Ref 3.2.3.3)

D.1.3.1 Requirement: A source in object space greater than 1 degree outside the field of regard shall not result in any perceptible point or edge like image within the field of regard.

D.1.3.2 Rationale: The EFVS should preclude off-axis information from folding into the primary FOR imagery, creating the potential for misleading or distracting imagery. An off-axis rejection requirement was established based on consensus industry specification.

D.1.4 **Jitter** (Ref 3.2.3.4)

D.1.4.1 Requirement: When viewed from the HUD eye reference point the displayed EFVS image jitter amplitude shall be less than 0.6 mrad. Jitter for this use is defined in SAE ARP 5288.

D.1.4.2 Rationale: Jitter – high frequency positional oscillations - can cause distracting symbology and image movement which degrades image quality, readability, and legibility. A minimum requirement was established which is identical to that of SAE ARP 5288. This implies that the EFVS and HUD cannot exhibit jitter greater than that of the HUD itself. The rationale is that the HUD requirement *already* stipulates the greatest allowable jitter.

D.1.5 **Flicker** (Ref 3.2.3.5)

D.1.5.1 Requirement: Flicker is brightness variations at frequency above 0.25 HZ per SAE ARP 5288. The minimum standard for flicker shall meet the criteria of SAE ARP 5288.

D.1.5.2 Rationale: Flicker –high frequency luminance variations - can cause mild fatigue and reduced crew efficiency. A minimum requirement was established which is identical to that of SAE ARP 5288. This implies that the EFVS and HUD cannot exhibit flicker greater than that of the HUD itself. The rationale is that the HUD requirement already stipulates the greatest allowable flicker.

D.1.6 **Image Artifacts** (Ref 3.2.3.6)

D.1.6.1 Requirement: The EFVS shall not exhibit any objectionable noise, local disturbances or an artifact that hazardously detracts from the use of the system (for example, burlapping, running water droplets, or internal system noise).

D.1.6.2 Rationale: The image artifact requirement is derived from FAA (and other agency) Certification Special Conditions issued to date, whereby the EFVS design shall minimize unacceptable display characteristics or artifacts (e.g. noise, ``burlap'' overlay, running water droplets) that obscure the desired image of the scene, impair the pilot's ability to detect and identify visual references, mask flight hazards, distract the pilot, or otherwise degrade task performance or safety.

D.1.7 **Image Conformality** (Ref 3.2.3.7)

D.1.7.1 Requirement: The accuracy of the integrated EFVS and HUD image shall not result in a greater than 5 mrad display error at the center of the display at a range of 2000ft (100ft altitude on a 3 degree glideslope). Errors away from the bore sight shall be as defined in SAE ARP 5288.

D.1.7.2 Rationale: The HUD shall provide a conformal display of EFVS information. The allowable display accuracy - as a measure of the relative conformality of the HUD/EFVS display with respect to the real world view – is specified.

D.1.7.3 In accordance with SAE ARP 5288, the total HUD system display accuracy error as measured from the HUD Eye Reference Point, should be < 5.0 mrad at the HUD boresight, with increasing error allowable toward the outer edges of the HUD.

D.1.7.4 The EFVS conformality/accuracy is a combination of the EFVS and the HUD. The accuracy of the integrated EFVS and HUD image is specified as being no greater than 5 mrad display error at the center of the display at a range of 2000ft (100ft altitude on a 3 degree glideslope). The 5 mrad display error is derived from the “allowable” HUD accuracy from SAE ARP5288 (5 mrad at the HUD boresight). There is no error allowed for the EFVS sensor, since it is assumed any error can be electronically compensated during installation. Errors away from the boresight shall be as defined in SAE ARP 5288.

D.1.7.5 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.

D.1.7.6 Under the EFVS Concept of Operations (Section 1), the aircraft is flown, essentially irrespective of the EFVS/HUD dynamic error, to the MDA/MDH 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 glidepath as the pilot flies the flight path vector and Glidepath Reference Line toward the EFVS image of the runway.

D.2 SENSOR/SENSOR PROCESSOR

D.2.1 Dynamic Range (Ref 3.2.3.8.1)

D.2.1.1 Requirement: The minimum required dynamic range for passive EFVS shall be 48db. For active EFVS, side lobes shall be 23db below the main beam, and 40db dynamic range plus Sensitivity Time Control (STC).

D.2.1.2 Rationale: Minimum dynamic ranges are provided for active and passive sensors. Sufficient dynamic range is a critical component in providing adequate image quality for object/scene detection, recognition, and identification. These values were established based on a consensus industry specification.

D.2.2 Sensor Image Calibration (Ref 3.2.3.8.2)

D.2.2.1 Requirement: Visible Image Calibrations and other built in tests that take longer than 100 milliseconds shall 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 NUC, the image shall be removed from the pilots display.

D.2.2.2 Rationale: This requirement 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.

D.2.3 Sensor Resolution (Ref 3.2.3.8.3)

D.2.3.1 Requirement: The EFVS shall adequately resolve a 60ft wide runway from 200ft height above touchdown zone elevation with a typical 3-degree glide slope.

D.2.3.2 Rationale: The sensor resolution performance requirement is first established by the fact that the sensor, as a *minimum*, shall adequately resolve (for pilot identification) the runway threshold and the touchdown zone to enable the intended function (see Table 3). The required sensor resolution is then established by providing this resolution at a minimum range (i.e., when the aircraft is at a 200 ft height above touchdown zone elevation position), thus, allowing the pilot to continue the descent below DA/DH or MDA/MDH. (These values do not take into account pilot decision time or actual atmospheric conditions, or the use of non precision approaches which may require greater distances.)

D.2.3.3 A 60 ft wide runway – the minimum runway width from ICAO which can support an instrument approach procedure – provides the pacing resolution.

D.2.4 **Passive Sensor Optical Distortion** (Ref 3.2.3.8.4)

D.2.4.1 Requirement: Optical distortion shall be 5% or less across the FOR as defined in 3.3.2 and no greater than 8% outside the minimal FOR.

D.2.4.2 Rationale: These values were established based on a consensus industry specification.

D.2.5 **Sensor Sensitivity** (Ref 3.2.3.8.5)

D.2.5.1 Requirement: The minimum required system performance for EFVS system sensitivity is either a Noise Equivalent Temperature Difference (NETD) of 50 mK, tested at an appropriate ambient temperature, for passive EFVS systems or -20db sm/sm from 200ft height above touchdown zone elevation with a typical 3-degree glide slope for active EFVS systems. Passive sensors for different visible or short-wave infrared sources may require very sensitive detectors, as specified by low Noise Equivalent Powers.

D.2.5.2 Rationale: These values were established based on a consensus industry specification. Exact performance values for passive EFVS sensors with a detector in the visible or short-wave infrared spectra are not confirmed at this time.

D.2.6 **Failure Messages** (Ref 3.2.3.8.6)

D.2.6.1 Requirement: Specific in flight failure message(s) for sensor failure and frozen image shall be displayed to the flight crew.

D.2.6.2 Rationale: The flight crew shall be provided in-flight failure messages to ensure timely reaction to potentially misleading information being displayed during critical phases of flight.

D.2.7 **Blooming** (Ref 3.2.3.8.7)

D.2.7.1 Requirement: The sensor shall incorporate features to minimize objectionable blooming. Objectionable blooming is defined as the condition that obscures the required visual cues defined in Table 3 at 100ft height above touchdown zone elevation.

D.2.7.2 Rationale: Blooming can create an unusable or objectionable image. Blooming to the extent that the required visual references are no longer discernable is unacceptable.

D.2.8 **Image Persistence** (Ref 3.2.3.8.8)

D.2.8.1 Requirement: The image persistence time constant shall be less than 100 milliseconds. However, burn-in or longer image persistence caused by high energy sources shall be removed from the image to comply with Section 3.2.3.6 Image Artifacts, by a secondary on-demand process (e.g., the NUC process).

D.2.8.2 Rationale: Image persistence can create objectionable image artifacts, unless the image persistence quickly decays (less than 100 msec). It may be difficult or impossible to meet this requirement if the image persistence is created for a high-energy source (e.g., the Sun), saturating the sensor elements. In this case, longer image persistence is allowable if Non-Uniformity Correction (NUC) can eliminate the image persistence in compliance with the requirement of Section 3.2.4.1.

D.2.9 **Dead Pixels** (Ref 3.2.3.8.9)

D.2.9.1 Requirement: Dead pixels or sensor elements that are replaced by a “bad pixel” replacement algorithm shall be limited to 1% average of the total display area, with no cluster greater than 0.02% within the minimum field of regard.

D.2.9.2 Rationale: A small number of disparate dead pixel elements can be effectively replaced by image processing but eventually, the algorithms will degrade the image quality and accuracy due to the shear number and closely-spaced location of the element. These values were established based on a consensus industry specification.

D.3 AIRCRAFT INTERFACE

D.3.1 Pilot Controls (Ref 3.2.4.1)

D.3.1.1 Contrast/Brightness Requirement: The minimum system shall include a control of EFVS display contrast/brightness that is sufficiently effective in dynamically changing background (ambient) lighting conditions, to prevent distraction of the pilot, impairment of the pilot's ability to detect and identify visual references, masking of flight hazards, or otherwise degrade task performance or safety. If automatic control for image brightness is not provided, it shall be shown that manual setting of image brightness meets the above criteria and does not cause excessive workload. (Ref 3.2.4.1.1)

D.3.1.2 Rationale: The pilot shall have an accessible means of controlling the EFVS image quality or to minimize its obscuration of the outside world during this critical phase of flight (i.e., DA/DH or MDA/MDH to 100 feet height above touchdown zone elevation). If automatic control is available, it shall be satisfactorily demonstrated to achieve these same objectives. The requirement is derived from FAA (and other agency) Certification Special Conditions issued to date for EFVS.

D.3.1.3 Display Control Requirement: A control shall be provided which permits the pilot flying to deactivate and reactivate the display of the EFVS image on demand without removing the pilot's hands from the primary flight controls (yoke or equivalent) and thrust control. (Ref 3.2.4.1.3)

D.3.1.4 Rationale: The pilot shall have an readily-accessible means of deactivate and reactivate of the EFVS image to expediently comply with existing 91.175 regulations. No lower than 100 feet, the pilot shall see the required visual landing references to continue the descent to landing. To do so, requires the pilot to look through the HUD (or look around the combiner). A readily-accessible declutter control (to remove the EFVS image from the HUD) provides the most efficient and effective means to provide a clear view of the outside for the pilot to see the required landing visual references. Since the current regulation does not prohibit that the EFVS be removed during the approach and landing, a readily-accessible means to reactivate the EFVS image allows the pilot, if they should so chose, to select the best possible information for them to successfully and safely complete the landing. The requirement is derived from FAA (and other agency) Certification Special Conditions issued to date for EFVS.

D.3.1.5 Control Access Requirement: The EFVS display controls shall be visible to, and within reach of, the pilot flying from any normal seated position. The position and movement of the controls shall not lead to inadvertent operation. The EFVS controls, except those located on the pilot's control wheel, shall be adequately illuminated for all normal background lighting conditions and shall not create any objectionable reflections on the HUD or other flight instruments. Unless fixed illumination of the EFVS controls is shown to be satisfactory under all lighting conditions for which approval is sought, there shall be a means to modulate it. (Ref 3.2.4.1.2)

D.3.1.6 Rationale: All necessary controls should be readily-accessible to the pilot, and properly illuminated, to avoid undue movement, workload, or distraction in a critical phase of flight. The requirement is derived from FAA (and other agency) Certification Special Conditions issued to date for EFVS.

D.3.2 Annunciations - EFVS (Ref 3.2.4.12)

D.3.2.1 Mode Annunciation Requirement: Any modes of EFVS operation shall be annunciated on the flight deck and visible to the crew. The modes of the EFVS operation shall be made available to the flight data recorder as required.

D.3.2.2 Rationale: The flight crew shall be aware of any EFVS operating modes as they may impact flight safety and performance. Similarly, these data should be available on flight data recorder for post-flight analysis, if required. The requirement is derived from FAA (and other agency) Certification Special Conditions issued to date for EFVS.

D.4 DISPLAY

D.4.1 Display Resolution of the HUD (Ref 3.2.5.1)

D.4.1.1 Requirement: The EFVS display shall adequately resolve a 60ft wide runway from 200ft height above touchdown zone elevation with a typical 3-degree glide slope.

D.4.1.2 Rationale: The performance of the EFVS includes the HUD. The HUD resolution should be no less than that provided by the EFVS, otherwise, the HUD resolution will be the limiting factor and it will not be sufficient to perform the intended function.

D.4.2 Imagery and Symbology Display (Ref 3.2.5.2)

D.4.2.1 Requirement: Imagery shall not degrade presentation of essential flight information on the HUD. (Ref 3.2.5.2)

D.4.2.2 Rationale: The EFVS should not adversely affect the basic performance of the HUD, and in particular, EFVS cannot degrade essential flight information to the extent that pilot workload, awareness, crew-decision making or safety is impaired because of it.

APPENDIX E

EVS/SVS/CVS MINIMUM SYSTEM PERFORMANCE STANDARD RATIONALE

Section 3.1 of this document presents minimum performance standards for an EVS/SVS/CVS and associated subsystem/functions that constitute required elements of minimum system performance. In the following, the rationale for these minimum performance standards elements is presented.

E.1 SYSTEM REQUIREMENTS RATIONALE

E.1.1 **EVS Image Characteristics** (Ref 3.1.3.1.1)

E.1.1.1 Requirement: On a head-down display, the relationship of the display field of regard to the actual field of view should be suitable for the pilot to smoothly transition from the head-down to the head-up, out-the-window real features.

E.1.1.2 Rationale: In order for the pilot to make a determination about whether the flight visibility (under US regulations) is sufficient to continue the approach and distinctly identify the required visual references using natural vision, the PFD relationship between the field of regard and actual field of view must not adversely affect the pilot's accurate identification and recognition of out-the-window references (e.g., runway, touchdown zone, etc.) or the pilot's visual accommodation when going from a compressed field of regard (head-down) to a conformal field of view (head-up and out-the-window).

E.1.2 **Data Refresh Rate** (Ref 3.1.3.1.1 & Ref 3.1.3.2.1)

E.1.2.1 Requirement: The image data shall be refreshed at 15 Hz or better.

E.1.2.2 Rationale: The data refresh rate was made consistent with the image requirements of AC 25-11A.

E.1.3 **Image Latency:**

E.1.3.1 Requirement: The image latency shall be less than 100 milliseconds where the latency is measured from the image source time of applicability to the display of the image.

E.1.3.2 Rationale: The image latency for a Primary Flight Display or HUD was made consistent with the image requirements of AC 25-11A.

E.1.4 **SVS Image Characteristics** (Ref 3.1.3.2.1)

E.1.4.1 Requirement: The relationship of the display field of regard to the actual field of view should be suitable for the pilot to smoothly transition from the head-down display to the head-up, out-the-window real features.

E.1.4.2 Rationale: In order for the pilot to make a determination about whether the flight visibility (under US regulations) is sufficient to continue the approach and distinctly identify the required visual references using natural vision, the PFD minification level must not adversely affect pilot accurate identification and recognition of out-the-window references (e.g., runway, touchdown zone, etc.) or pilot visual accommodation when going from a compressed field of regard, head-down to the head-up, out-the-window view).

E.1.5 **Scene Range** (Ref 3.1.3.2.1)

E.1.5.1 Requirement: The scene range should be the natural horizon for both ego-centric and exo-centric displays. For systems intended for use in approach, missed approach, take-off, and departure operations, the scene range shall be whichever is less of natural horizon, 40 nautical miles, or 10 minutes at maximum cruise speed.

E.1.5.2 Rationale: Scene range includes the less of natural horizon, 40 nautical miles, or 10 minutes of maximum cruise speed. The rationale for 40 nautical miles is in section 2.1.2.2 item k). The latter value was chosen to account for low altitude, low speed aircraft.

E.1.6 **SVS Obstacle Database** (Ref 3.1.3.2.7)

E.1.6.1 Requirement: Synthetic vision databases shall include all available physical hazards greater than 200 feet above ground level, not just terrain. The system shall neither disregard nor corrupt obstacles available in the database greater than 200 feet above ground level. Obstacles displayed shall be those deemed hazardous to the phase of flight.

E.1.6.2 Rationale: To ensure crew strategic awareness of physical hazards and not just terrain, a depiction of hazards 200 feet or greater in height on any SVS display was chosen. This value was established based on a consensus industry specification. Obstacles displayed shall be those deemed hazardous to the phase of flight to reduce display clutter.

E.1.7 **CVS Fusion of EVS and SVS Images** (Ref 3.1.3.3)

E.1.7.1 Requirement: Fusion of EVS and SVS shall require the images to be aligned within 5 milliradian (mrad) laterally and vertically at the boresight of the display.

E.1.7.2 Rationale: This requirement was derived based upon EFVS conformality/accuracy requirements. The accuracy of the integrated EFVS and HUD image is specified as being no greater than 5 mrad display error at the center of the display at a range of 2000ft (100ft altitude on a 3 degree glideslope). The 5 mrad display error is derived from the “allowable” HUD accuracy from SAE ARP5288 (5 mrad at the HUD boresight).

APPENDIX F

SAMPLE EFVS FLIGHT TEST PLAN

F.1 OBJECTIVES

The objectives of the flight test program are to ensure that the system performs its intended function when installed, and to demonstrate that the EFVS is operationally acceptable and safe. The objectives of the flight test program are not to quantitatively measure the detection performance of the sensor.

At the end of the flight test program, the EFVS should have demonstrated it is capable of providing references before they are visible using natural vision. The EFVS should enable descent below DA/DH or MDA/MDH using enhanced flight visibility when visual references would not otherwise be visible using natural vision.

F.1.1 The combination of the EFVS imagery with the HUD symbology and the relationship between the two in terms of brightness and contrast is a critical issue with respect to the installation; therefore, for the purpose of certification flight testing, the environmental conditions chosen shall be such that these parameters are adequately evaluated.

F.1.2 Environmental conditions shall be chosen to exercise both the automatic and manual control of items such as brightness, contrast and gain, and any other parameter that affects the image displayed to the pilot.

F.1.3 Testing shall include an appropriate number fault-free approaches (see note below) in as many of the conditions listed below as practicable and as applicable. Past experience has shown more than 50 fault-free approaches have been needed.

- Night VFR conditions over various topography (urban, rural, snow covered, etc.)
- Day and night IFR conditions over various topography
- Representative levels of rainfall
- Representative levels of snowfall
- Representative levels of fog
- Haze
- Representative sun angles
- Representative airport lighting configurations
- Representative airport/runway surface conditions (dry, wet, standing water, snow cover)
- Representative thermal crossover conditions
- Representative crosswind and off-set conditions regarding lateral field of regard
- Representative runway surface types (dirt, asphalt, concrete, etc.)
- Representative adjacent surfaces types (dirt, asphalt, concrete, etc.)

The above lists shall be assessed against the specific sensor type and additional test conditions may be required.

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

i. HUD or EFVS failure has occurred.

ii. 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 image.

iii. *At 100 ft above TDZE the airplane is not positioned so that the cockpit is within, and tracking so as to remain within, the lateral confines of the runway extended.*

iv. *Due to a confusing or misaligned image the touchdown will be too short or too long.*

v. *The EFVS image degrades the flyability of the display such that a successful approach to DA/DH or MDA/MDH is not possible.*

F.1.4 Test Points

Testing shall include all phases of flight for which the applicant seeks approval of the system.

In addition to the success criteria for approaches, the EFVS minimum performance standards require the assessment of the HUD/EFVS display when used in conjunction with the flight instrumentation required in FAR 91.175 and listed in Section 1.3.1.5 of this document.

The following evaluations shall be performed in representative configurations.

F.1.5 Evaluation during Taxi

F.1.5.1 Assess EFVS/HUD combination while taxiing and making identification of objects on runways, taxiways, parking aprons.

F.1.5.2 Verify that the use of EFVS does not cause confusion or misleading information when viewing through the HUD/EVS all types of airport runway, taxiway, obstruction, and barrier lighting and signage as well as the navigation, taxi, and landing lights of other airplanes.

F.1.5.3 Verify that the HUD combiner with the image displayed does not significantly alter the color perception of the external scene.

F.1.5.4 Assess lack of burn-in or blooming from high intensity heat sources such as running engines, etc.

F.1.6 Take-off Evaluation

F.1.6.1 Ensure correct pitch angle is achieved using HUD pitch reference target.

F.1.6.2 Verify symbology in EFVS mode is clear, visible and does not cause over-control or oscillations in acquiring and maintaining the required ground track.

F.1.6.3 Confirm that the HUD with EFVS provides the pilot with a quick-glance (instant) sense of flight parameters.

F.1.6.4 Assess the transition to different selected vertical modes.

F.1.6.5 Evaluate the EFVS image during the take off roll and throughout the climb segment, against the attributes listed in the pilot evaluation matrix (Section F.5.0).

F.1.7 Climb and Descent and Lateral Modes Evaluation

F.1.7.1 Climb, descent and lateral modes should be evaluated in day and night IMC and VMC to assess HUD/EFVS compatibility.

F.1.7.2 During vertical and lateral guidance maneuvers evaluate the EFVS image against the attributes listed in the pilot evaluation matrix (Section F.5.0).

F.1.8 Instrument Approaches

During any instrument approach for which approval is sought, HUD/EFVS compatibility shall be evaluated against the attributes listed in the pilot evaluation matrix (Section F.5.0).

F.1.9 Flare Landing and Go Around

F.1.9.1 Whilst using EFVS during final approach and through the flare (below 50 Ft), touchdown roll or go-around, assess the transition to natural vision and compatibility of the guidance when following the HUD/EFVS flight cues.

F.1.9.2 Confirm landing rollout information, if provided in the display, is sufficiently visible to the pilot and does not cause over-control or oscillations in acquiring and maintaining the required ground track.

F.1.9.3 Throughout the approach guidance maneuvers evaluate the EFVS image against the attributes listed in the pilot evaluation matrix (Section F.5.0).

F.2 CO-PILOT MONITOR

If one is fitted, assess the ergonomic aspects of the image on the co-pilot's EFVS monitor.

F.2.1 Verify satisfactory display of imagery in all lighting and environmental conditions and that dimming controls of the display are adequate.

F.2.2 If the display has dual purposes verify the means of switching the display to being the EFVS monitor and back is satisfactory and clearly evident.

F.2.3 Verify no flicker and/or jitter in the display

F.2.4 Verify that no objectionable glare or reflections are generated by the display or are visible in the display.

F.2.5 Verify that the co-pilot's use of the EFVS monitor does not require undue head/body movement away from their normal scan pattern or their normal seated position.

F.3 FAILURE CASES

Failure cases to support the FHA shall be assessed as required, e.g. uncommanded full image brightness, misaligned image, frozen image, etc. in addition to the approaches required in Section this appendix.

F.4 ICE PROTECTION SYSTEM EVALUATION

F.4.1 If the EFVS sensor installation has ice protection capability the EFVS image shall be evaluated with the ice protection on and off in representative environmental conditions.

F.4.2 Icing of the sensor fairing/radome shall be appropriately assessed in accordance with the certified flight envelope.

F.5 EVALUATION MATRIX

The following pilot's evaluation matrix shall be used to support the testing described in Appendix F, above.

A	Confirm that crew workload is not adversely affected by the HUD/EFVS installation.
B	Verify no adverse physiological effects from using the HUD/EFVS (e.g., fatigue, eye strain).
C	Verify HUD/EFVS symbology is visible within pilot Field of View (FOV) (When viewed by both eyes from any off-centre position within eye box, non-uniformities shall not produce perceivable differences in binocular view).
D	Verify no jitter or flicker of HUD/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 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 cockpit window as a result of EFVS imagery and HUD symbology.
K	Confirm that the pilot's ability to detect hazards, maneuver, avoid traffic, terrain or other obstacles, is not impaired or degraded by the display of EFVS imagery.
L	Confirm that there is no discrepancy between the conformal HUD symbols, sensor image and the outside view through the windshield.
M	Verify that outside visibility as viewed through combiner sensor imagery is adequately aligned and conformal to the external scene and HUD symbology.
N	Confirm that the EFVS 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 his/her task performance or safety.
T	Verify identification of approach lights, runway threshold, touchdown zone etc. as per FAR 91.175(l).
U	Confirm that the HUD EFVS image is suitable and performs its intended function.
V	Confirm the sensor image on the co-pilot's display (if installed) is useable and performs its intended function.
W	Evaluate the EFVS image during the take off roll and throughout the climb segment, against the attributes listed in the attached pilot evaluation matrix.
X	During vertical and lateral guidance maneuvers evaluate the EFVS image against the attributes listed in the attached pilot evaluation matrix.