

**Human Engineering Considerations for Implementing Enhanced
Synthetic Vision Systems in Vertical Flight Capable Platforms**

RATIONALE

The use of enhanced visual scene content as both a tool to increase situation awareness and as a sole flight guidance display has increased and will continue to increase. Correct implementation of these types of displays is essential and critical to safe vertical flight-specific operations.

SAE G-10 Aerospace Behavioral Engineering Technology (ABET) Committee, specifically the G-10V Vertical Flight Subcommittee, has been tasked by Helicopter Association International (HAI) to provide document guidance to implement Enhanced Synthetic Vision Systems (ESVS) into vertical flight aircraft (rotorcraft and powered lift air vehicles) used in operations where there is an increasing mishap record associated with loss of SA and inability to operate at low altitude in degraded visual environments (DVE).

FOREWORD

Some of the intended uses of vertical flight and/or rotary-winged platforms (e.g., rotorcraft and powered lift vehicles), are inherently different than conventional fixed wing platforms. The issues associated with enhanced synthetic vision systems implemented into vertical flight platforms have some special considerations that must be addressed. These special considerations are related to these VF platforms ability to operate in off-airport and non-prepared facilities and unimproved landing areas.

This document complements the SAE G-10 Enhanced Synthetic Vision Systems (ESVS) Subcommittee ARP5677 Human Engineering Considerations for Enhanced Synthetic Vision Systems by identifying and recommending human engineering best practices in the design of ESVS for, and implementation into, vertical flight platforms. It also draws from ARD50019, Human Engineering Issues for Enhanced Vision Systems. This document is intended to provide a central source for recommending human engineering applications concerning ESVS in vertical flight platforms as an aid for development, design and implementation. Any comments or information concerning the data contained in the document shall be directed to the subcommittee chairman.

DEFINITION

An enhanced synthetic vision system (ESVS) generates and displays visual imagery based upon sensor information of the out-of-cockpit scene in front of an aircraft, combined with a computer-generated visual scene representing the out-of-the-cockpit view of terrain and selected scene data. The sensor(s) is/are designed to penetrate degraded visual environmental conditions better than unaided human vision, while the computer generated scene is unaffected by environmental conditions.

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1. SCOPE

The scope of this Vertical Flight document is limited to human behavioral technologies associated with design and/or implementation of Enhanced Synthetic Vision Systems (ESVS) in vertical flight aircraft. Any overlap into logic problems or hardware/software design shall be considered to be incidental to the human factors issues. Where the performance characteristics of specific technologies are relevant they will be identified, and where performance criteria are relevant to specific intended functions/use they will be identified.

From a regulatory view, intended function (Full Flight Guidance or Information/Situation Awareness support) has a tremendous effect upon the design of an ESV System. However from a Human Engineering standpoint, the information on display must be discernible and comprehensible to the human operator in both cases and differences may be primarily in information content (required to support a specific task).

The document is independent of candidate technologies and concentrates on human interface criteria. This document does not include consideration of detection and/or display of air targets or integration of systems such as TCAS.

1.1 Purpose

This document addresses human factors considerations and requirements in data access, display comprehension, interpretation and application of imagery and integrated symbology in Enhanced (sensor) and Synthetic (database) Vision Systems as applicable to vertical flight platforms, and is a compilation of human factors recommended practices in the design and/or implementation of ESVS. It may be updated to reflect research and development results and as the technology improves and applications expand, the coverage of the document will be expanded.

2. REFERENCES

A full bibliography has been compiled and is attached as Appendix A.

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

ARP571	Flight Deck Controls and Displays for Communication and Navigation Equipment for Transport Aircraft
AS580	Pilot Visibility from the Flight Deck Design Objectives for Commercial Transport Aircraft
ARP1068	Flight Deck Instrumentation, Display Criteria and Associated Controls for Transport Aircraft
AIR1093	Numerical, Letter and Symbol Dimensions for Aircraft Instrument Displays
ARP1782	Photometric and Colorimetric Measurement Procedures for Airborne Direct View CRT Displays
ARP1874	Design Objectives for CRT Displays for Part 25 (Transport) Aircraft
ARP4032	Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays
ARP4102	Flight Deck Panels, Controls, and Displays

ARP4107	Aerospace Glossary for Human Factors Engineers
ARP4155	Human Interface Design Methodology for Integrated Display Symbology
ARP4256	Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft
ARP5288	Transport Category Airplane Head Up Display (HUD) Systems
ARP5677	Human Engineering Considerations for Airborne Implementation of Enhanced Synthetic Vision Systems
AS8034	Minimum Performance Standard for Airborne Multipurpose Electronic Displays
AS8055	Minimum Performance Standard for Airborne Head Up Display (HUD)
ARD50019	Human Engineering Issues for Enhanced Vision Systems

2.2 Other Applicable References

AMJ25. 1309	System Design Analysis (EASA)
ADS-33	Handling Quality Ratings
ED-179B	MASPS for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems and Enhanced Flight, EUROCAE, 2011
FAA AC 20-175	Controls for Flight Deck Systems
FAA AC 23-26	Synthetic Vision and Pathway Depictions on the Primary Flight Display
FAA AC 25-11A	(of 06-21-07) Transport Category Airplane Electronic Display Systems
FAA AC 120-29a	(of 12 August 2002) Criteria for Approval of Category I and Category II Weather Minima for Approach
FAA AC-23.1309-1C	Equipment, Systems, and Installations in Part 23 Airplane
FAA AC-23.1311-1B	Installation of Electronic Display Instrument Systems In Part 23 Airplanes
FAA AC-25.1309-1A	System Design Analysis
FAA AC-150/5390-2_	Heliport Design
FAA AC-150/5390-3_	Vertiport Design

Flight Safety Foundation Human Factors & Aviation Medicine, Volume 51 no. 2, Section 6.56.9 Image Quality, http://flightsafety.org/hf/hf_mar-apr04.pdf

ISO FDIS 9241-8 Requirement for Display Colours

RTCA DO-200a / EUROCAE ED-76 "Standards for Processing Aeronautical Data"

RTCA DO-276 User Requirements for Terrain and Obstacle Data

MIL-STD-1472F Human Engineering Design Criteria for Military Systems, Equipment and Facilities

NATO RTO Technical Report HFM-091/RTG-027: Common Methodological Basis for Evaluation and Testing of Visionic Devices

2.3 Regulatory Publications

FAR Part 23	Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes
FAR Part 25	Airworthiness Standards: Transport Category Airplanes (EASA CS Part 25)
FAR Part 25.1321	Airworthiness Standards: Transport Category Airplanes; Arrangement and Visibility
FAR Part 27	Airworthiness Standards: Normal Category Rotorcraft
FAR Part 29	Airworthiness Standards: Transport Category Rotorcraft
TSO-C113	Airborne Multipurpose Electronic Displays
RTCA DO-309	Minimum Aviation System Performance Standards (MASPS) for Helicopter Terrain Awareness and Warning System (HTAWS) Airborne Equipment, March 13, 2008, RTCA SC-212
RTCA DO-315B	Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems and Enhanced Flight Vision Systems, SC-213, Washington, DC, June 2011
RTCA SC-213	(Joint with EUROCAE WG-79) Enhanced Flight Vision Systems/Synthetic Vision Systems, (EFVS/SVS)
MIL-STD-1472F	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
NATO RTO	Technical Report HFM-091/RTG-027: <u>Common Methodological Basis for Evaluation and Testing of Visionic Devices</u> ; Chapter 3 - Sensor Technologies for Enhanced and Synthetic Vision Systems
NATO RTO	Technical Report HFM-162 Rotary-Wing Brownout Mitigation: Technologies and Training, Chapter 4 TECHNOLOGY: SENSORS AND DATA PROCESSING
NASA Report ARL-02-6/NASA-02-4, 2002,	<u>Spatial Awareness Biases</u> (Wickens)

2.4 Definition of Terms

ACTUAL NAVIGATION PERFORMANCE (ANP): A measure of the current estimated navigation performance, excluding Flight Technical Error (FTE). Actual Navigation Performance is measured in terms of accuracy and integrity, and may be affected by the type and availability of navigation signals and equipment. NOTE: Also see Estimated Position Uncertainty (EPU).

ALLOCENTRIC: Scene-based frame of reference particularly with respect to the object's spatial location; an observer-independent (possibly earth-fixed) frame of reference.

CLUTTER: Clutter is an attribute of poorly organized and crowded displays. A cluttered display is one which uses an excessive number and/or variety of symbols, colors, or small spatial relationships. This causes increased processing time for display interpretation. It generally results in reduced display legibility, and/or in increases in the time needed to locate and interpret information on the display.

COGNITIVE CAPTURE: Also known as cognitive tunneling, task fascination or "attentional" capture. The compelling phenomenon in which the observer is too focused on the instrumentation (display) and not on the whole environment.

COMBINED VISION SYSTEM (CVS): The CVS concept involves a combination of synthetic and enhanced systems. Some examples of a CVS include database-driven synthetic vision images combined with real-time sensor images superimposed and correlated on the same display.¹

COMMAND INFORMATION: Information that directs the pilot to follow a course of action in a specific situation (e.g., Flight Director or TCAS RA - resolution advisory).

COMMAND REFERENCE FRAME: A symbol, appropriately colored, indicating the position within which the pilot shall place the flight path marker to affect the desired flight performance response.

CONFORMAL INFORMATION: Information which correctly overlays the image of the real world, irrespective of the pilot's viewing position. Conformal means having a 1:1 angular and scalar relationship. For displays the field of regard is the same as the field of view.

COPLANAR DISPLAYS: Devices whose display surfaces lie in the same two dimensional plane. Also use this to describe views like the plan view and VPD.

DATA FUSION: Combining or consolidation and integration of separate data sources into a single entity where each data source is indistinguishable.

DEGRADED VISUAL ENVIRONMENT: Atmospheric conditions where the visibility is restricted by obscurants or environmental conditions optical perception of the pilot in the loop is diminished to less than VMC conditions as defined by FAR/CAR.

DESIGN EYE POSITION: The midpoint of the line segment of the vision line connecting two points that represent the predicted eye positions of the extremes of the aircrew population.

DESIGN EYE POSITION (DEP): The location, specified by the airframe manufacturer, from which the pilot can view cockpit instrumentation, have adequate external view, and can reach cockpit controls. (FAA AC-25.773-1)

DESIGN VIEWING ENVELOPE(S): Range of possible angles, horizontal and vertical from the normal axis of the display, from which the unit would be viewed. There are two envelopes of concern: the primary envelope which defines the range of critical viewing angles where the crew most often views the display, and the secondary envelope which describes the peripheral viewing angles which are used by the crew and others, but with less frequency and criticality. The secondary viewing envelope usually includes those angles needed for cross-cockpit viewing.

DTEDDIGITAL TERRAIN ELEVATION DATA: A standard of digital datasets which consists of a matrix of terrain elevation values; standards for Level 1 (3 arc second ~90 meter) and Level 2 (1 arc second ~ 30 meter) DTED.

EGOCENTRIC: A presentation referenced to the aircraft/pilot, rather than the outside world.

ENHANCED FLIGHT VISION SYSTEM: 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) 3D perspective imagery with primary flight symbology through the use of imaging sensors, such as a forward looking infrared, millimeter wave radiometry, millimeter wave radar, low light level image intensifying. From Department of Transportation, Federal Aviation Administration 14 CFR Parts 1, 91, et al., Enhanced Flight Vision Systems; Final Rule.

ENHANCED VISION SYSTEM (EVS): An electronic means to provide the flight crew with a sensor derived or enhanced image of the external scene (e.g., NVS, millimeter wave radar, Forward Looking Infrared).

ENHANCED/SYNTHETIC VISION SYSTEM (E/SVS): An integrated or fused display system which combines sensor-enhanced and synthetic vision elements to provide the pilot with an optimally-resolved, valid, and accurate representation of the real-world for external visual reference.

¹ Federal Aviation Administration AC 20-167.

ESTIMATED POSITION UNCERTAINTY (EPU): The measurement of the horizontal figure of merit of the actual aircraft position related to predicted position. HFOM is a measure of the accuracy of an aircraft's reported position. It is the radius of a circle, centered on an aircraft's reported position, such that the probability of the true position lying outside that circle is 5% or less. (Revised DO-242A ADS-B MASPS)

EPU is a measure based on a defined scale, in nautical miles, which conveys the current position estimation performance (circular error of probability - CEP); represents the 95% accuracy performance of the navigation solution, computed based on the error characteristics of the particular sensors being used and the variance of the individual sensors position with respect to other sensors.

EXOCENTRIC: A presentation referenced to a stationary point in the outside world, or to a position relative to the aircraft (e.g., a tethered "wingman" view), a view from a position away from the pilot position.

FIELD OF REGARD: All of the points of the physical environment that can be perceived by a stable unaided eye. The angular extent of the external world that can be represented on a display.

FIELD OF VIEW: The angular extent of the physical display surface referenced to the pilot eye position, often called geometric field of view (characterized as degrees/minutes of visual angle).

FIGURE OF MERIT: In referring to image registration, the FOM is the composite measurement of the accuracy of the registration of the image data to actual data.

FINAL APPROACH AND TAKEOFF AREA (FATO): An area over which the final phase of the approach to a hover, or a landing is completed and from which the takeoff is initiated.

FLICKER VERTIGO: An imbalance in brain-cell activity caused by exposure to low-frequency flickering (or flashing) of a relatively bright light, normally caused by stroboscopic effect of rotor blade interruption of external light, e.g., sun light, and/or, at night, anti-collision and/or other lights reflected off of rotor blades, that can cause disorientation leading to loss of control or seizure.

FLIGHT TECHNICAL ERROR: The accuracy with which the aircraft is controlled as measured by the indicated aircraft position with respect to the indicated command or defined flight path position.

FLIGHT PATH MARKER: The display symbol used to indicate the vertical and lateral trajectory (i.e., flight path) of the aircraft. This symbol may indicate the measured aircraft flight path (i.e., Flight Path Vector, FPV) or it may indicate a predicted or quickened aircraft flight path.

FLIGHT PATH VECTOR: The vertical and lateral trajectory (i.e., flight path) of the aircraft, indicating the measured aircraft flight path (i.e., Flight Path Vector, FPV), actual (immediate) or predicted or quickened.

FUSION: Fusion as applied to this document refers to integrated blending of synthetically-derived imagery or digital terrain data with real-time sensor-derived data.

GUIDANCE: Information used during manual or automatic control, or monitoring of automatic control of an aircraft that is of sufficient quality to be used by itself for the intended purpose of achieving a particular flight path.

GHOSTED: Symbolology that is grayed out, lower contrast/brightness or dashed to indicate changed/alterd parameter.

HELIPAD: A fabricated surface providing a clearly marked surface away from obstacles where a helicopter can safely land and/or takeoff.

HRTI HIGH RESOLUTION TERRAIN INFORMATION: Higher resolution terrain data, resolution for Level 3 DTED is a 1/3rd arc second (~10 meter), Level 4 is 1/9th arc second (~3 meter) and Level 5 DTED is 1/27th arc second (~1 meter).