

Proposed Special Condition on Enhanced Flight Vision System (EFVS) with Ops credit

Applicable to Falcon F7X

Introductory note:

The following Special Condition has been classified as an important Special Condition and as such shall be subject to public consultation, in accordance with EASA Management Board decision 02/04 dated 30 March 2004, Article 3 (2.) of which states:

"2. Deviations from the applicable airworthiness codes, environmental protection certification specifications and/or acceptable means of compliance with Part 21, as well as important special conditions and equivalent safety findings, shall be submitted to the panel of experts and be subject to a public consultation of at least 3 weeks, except if they have been previously agreed and published in the Official Publication of the Agency. The final decision shall be published in the Official Publication of the Agency."

Statement of Issue

Dassault Aviation proposes to install an Enhanced Flight Vision System (EFVS) on the Falcon F7X aircraft for approach operations down to 100 ft HAT (Height Above Threshold).

The EFVS consists of an infrared (IR) sensor unit projecting a monochrome display-format on a Flight Dynamics Head-Up Display (HUD). The infrared sensor unit is mounted on top of the aircraft nose under a fairing with a sapphire viewing window. The HUD is modified to display forward-looking infrared imagery in superposition of current HUD symbology. The IR image can also be repeated Head Down and be displayed on a Multi-function Display Unit (MDU) window of the Honeywell EASy avionics suite.

The approach operation down to 100 ft HAT is considered to be a new use of the system, which features new and novel technology to display video raster imagery in the pilot field of view.

This Special Condition proposes criteria regarding pilot's compartment view (JAR 25.773), and also acceptable means of compliance for the airworthiness approval of this system.

Note : Specific operational minima may be established in accordance with operational regulations for straight-in approaches conducted with EFVS equipped aircraft. These minima are based on the concept of double decision: the first decision to continue the approach at the published DA/MDA is based on the acquisition of visual references through the EFVS imagery and the second decision at 100ft HAT is based on the "direct view" of actual outside visual references.

Falcon F7X - Special Condition F-47

- Enhanced Flight Vision System (EFVS) with operational credit -

The applicant is requested to address the following :

1. Identification of intended function

The applicant is requested to precisely define the intended function(s) of the EFVS.

The design of the EFVS installation must be appropriate for its intended function, and the system must perform its intended function in all foreseeable operating conditions, without adversely affecting the level of safety or operation of other systems.

Associated limitations and Normal, Abnormal and Emergency procedures will have to be defined and incorporated in the Airplane Flight Manual.

2. Human factor considerations related to the intended function

The use of the EFVS for operational credit down to 100 ft is considered to be a novel feature as per CS 25.1302.

3. Special Condition for pilot's compartment view

The EFVS uses new and novel technology that displays video raster imagery in the field of view regulated by CS 25.773. This rule does not permit distortions and reflections in the pilot's compartment view that can interfere with normal duties and was not written in anticipation of such technology. The video image potentially interferes with the pilot's ability to see the natural scene in the centre of the forward field of view.

Unlike the pilot's natural forward vision, the EFVS image is infrared-based, monochrome, 2-dimensional (i.e. no depth perception) and of lower resolution. While the pilot may be readily able to see around and through small individual stroke-written symbols on the HUD, the pilot may not be able to see around or through the image that fills the display without some interference of the outside view. Nevertheless, the EFVS should be capable of meeting an equivalent level of safety when considering the combined view of the image and the outside scene which is visible to the pilot through the image. It is essential that the pilot can use this combination of image and natural view of the outside scene as safely and effectively as the pilot compartment view currently available without the EFVS image.

Since CS 25.773 does not provide for any alternatives or considerations for such a new and novel system, it is necessary to establish safety requirements that assure an equivalent level of safety and effectiveness of the pilot compartment view as intended by that rule.

The following special conditions apply under the provision of Part 21A.16B to provide the unique pilot compartment view requirements for the EFVS installation:

- a) EFVS imagery on the HUD must not degrade the safety of flight or interfere with the effective use of outside visual references for required pilot tasks during any phase of flight in which it is to be used.
- b) To avoid unacceptable interference with the safe and effective use of the pilot compartment view, the EFVS device must meet the following requirements:
 - (i) EFVS design must minimize unacceptable display characteristics or artefacts (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.
 - (ii) Control of EFVS display brightness must be sufficiently effective, in dynamically changing background (ambient) lighting conditions, to prevent full or partial blooming of the display that would distract the pilot, impair the pilot’s ability to detect and identify visual references, mask flight hazards, or otherwise degrade task performance or safety. If automatic control for image brightness is not provided, it must be shown that a one time manual setting is satisfactory.
 - (iii) A readily accessible control must be provided that permits the pilot to immediately deactivate and reactivate display of the EFVS image on demand.
 - (iv) The EFVS image on the HUD must not impair the pilot’s use of guidance information or degrade the presentation and pilot awareness of essential flight information displayed on the HUD, such as alerts, airspeed, flight path, attitude, altitude and direction, approach guidance, wind shear guidance, TCAS resolution advisories, unusual attitude recovery cues.
 - (v) The EFVS image and the HUD symbols, which are spatially referenced to the pitch scale, outside view and image, must be scaled and aligned (i.e., conformal) to the external scene and, when considered singly or in combination, must not be misleading, cause pilot confusion, or increase workload. There may be airplane attitudes or cross-wind conditions which cause certain symbols, such as the zero-pitch line or flight path vector, to reach field of view limits such that they cannot be positioned conformably with the image and external scene. In such cases, these symbols may be displayed, but with an altered appearance which makes the pilot aware that they are no longer displayed conformably (for example, “ghosting”).
 - (vi) A HUD system used to display EFVS images must, if previously certified, continue to meet all of the requirements of the original approval.
- c) The safety and performance of the pilot tasks associated with the use of the pilot compartment view must not be degraded by the display of the EFVS image. Pilot tasks which must not be degraded by the EFVS image include:
 - (i) Detection, accurate identification and manoeuvring, as necessary, to avoid traffic, terrain, obstacles, and other hazards of flight.

- (ii) Accurate identification and utilization of visual references required for every task relevant to the phase of flight.
- d) Appropriate limitations must be stated in the Operating Limitations section of the Airplane Flight Manual to prohibit the use of the EFVS for functions that have not been certified.

4. Acceptable Means of Compliance

Depending on the intended function as defined by the Applicant, EASA proposes to use the applicable sections of EUROCAE document ED-179 titled “MINIMUM AVIATION SYSTEM PERFORMANCE STANDARDS (MASPS) For ENHANCED VISION SYSTEMS, SYNTHETIC VISION SYSTEMS, COMBINED VISION SYSTEMS And ENHANCED FLIGHT VISION SYSTEMS”, as published in December 2008.

In addition to ED-179, the following criteria are proposed by EASA:

a) Image Characteristics

- (i) Resolution. The HUD system raster resolution specification should be developed by the applicant and shown to provide adequate definition at the HUD in all foreseen operation conditions.
- (ii) Luminance. The HUD raster luminance should be adequate to display a minimum number of grey shades (i.e. detectable levels of luminance), specified by the applicant to meet the intended function in the background luminance conditions which are representative of the environment in which the HUD and sensor system is intended to operate. The applicant should specify the maximum background luminance in which the HUD and sensor system is intended to operate and the minimum number of grey shades it needs to display.
- (iii) Contrast Variation. The contrast ratio between sequential grey shades should be sufficient to make them detectable with appropriate HUD brightness and contrast settings, excluding the contribution of ambient background (see SAE AS 8055 for appropriate minimum contrast ratios).
- (iv) Low Level Luminance. The HUD should be capable of providing a very dim, easily controllable image free of background glow in areas not displaying information in night conditions.

This can be shown by demonstrating that in a dark ambient background, with symbols and peak white video appropriately adjusted, a minimum number of shades of grey specified by the applicant should be visible and the areas of the raster which are blank should not be visible (see AS 8055 for appropriate levels).
- (v) Luminance Uniformity. The variation in intensity between any two points within 10° of each other or within the monocular FOV should not be excessive when a flat field signal is applied. SAE AS 8055 defines luminance uniformity and provides an acceptable method of calculating it.
- (vi) Display Quality. The EFVS imagery should have no noticeable display noise, artefacts objectionable flicker or jitter (as defined by SAE AS 8055), that impair the use of the system.

- (vii) Display Dynamics. The system operation should not be adversely affected by aircraft manoeuvring or changes in attitude encountered in normal operation.

For those elements of the display that are normally in motion, any jitter, jerkiness, or ratcheting effect should neither be distracting nor objectionable. The image update rate should be compatible with the EFVS intended function.

Any parameter lag (i.e. latency) introduced by the display system should be consistent with the airplane control task associated with that parameter. In particular, display system lag (including the sensor) for attitude should be demonstrated not to be misleading or confusing to the pilot.

- (viii) Image Controls. Controls for image and symbology display parameters such as brightness, sensor gain, contrast, should provide independent adjustment for the image and symbology. For parameters that need adjustment for changes in ambient light levels, and other dynamic environmental conditions, if automatic control for these adjustments is not provided, it must be shown that a one-time manual setting is satisfactory.

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

b) Installation.

- (i) Control Visibility and Accessibility. The EFVS display controls must be visible to, and within reach of, the pilot from any normal seated position. The position and movement of the controls must not lead to inadvertent operation. As required by JAR 25.1381, the EFVS controls, except those located on the pilot's control wheel, must be adequately illuminated for all normal background lighting conditions and must not create any objectionable reflections on the HUD or other flight instruments. Unless fixed illumination of the EFVS controls is shown to be satisfactory under all lighting conditions for which approval is sought, there must be a means to modulate it.
- (ii) Cockpit Integration. To the greatest extent practicable, the EFVS controls should be integrated with other controls, to minimize the crew workload associated with EFVS operation and to ensure flight crew awareness of engaged flight guidance modes.
- (iii) Conformal Display. The HUD symbology is conformal. This may not be the case of the EFVS image e.g. because of the offset of the camera from the pilot's eye-point. Therefore, the conformality of the EFVS display should be evaluated and demonstrated to be adequate for the intended function, for all foreseeable operation conditions (including engine out condition) and phases of flight where the use of the system is expected.

c) System Requirements

- (i) Intended Function. The EFVS system must be shown to perform its intended function for all foreseeable operation conditions and phases of flight where the use of the system is expected. The normal operation of the EFVS must not adversely affect, or be adversely affected by other airplane systems.
- (ii) Safety Assessment. The criticality of the EFVS system's function to display imagery, including the potential to display hazardously misleading information, should be assessed according to CS 25.1309, AMC 25-11 paragraph 4.a., and AMC 25.1309. All assumptions and alleviating flight crew actions that are considered in the EFVS safety analysis must be validated during testing for incorporation in the AFM limitation section, procedures section or for inclusion in type-specific training. The Functional Hazard Assessment given in Appendix C of ED-179 is only provided as an example for information and the actual failure conditions and hazard classifications may differ depending on the actual design, the intended function and the associated flight crew procedures. The use of this Appendix C is therefore not recommended and no credit can be claimed for the hazard classifications and criticalities mentioned in it. The safety analysis must show that the integrated system, consisting of the HUD components and EFVS components, meets critical signal integrity requirements for the airplane, HUD and EFVS. System and subsystem malfunctions which are not shown to be Extremely Improbable must be demonstrated in a simulation or in flight. The malfunction annunciation and fault detection schemes must demonstrate operation to the designed level of integrity.
- (iii) HIRF. The EFVS system must be shown to comply with acceptable high intensity radiated fields (HIRF) protection criteria, electromagnetic interference (EMI) and system lightning protection criteria.
- (iv) Recording. The EFVS should be taken into account when showing compliance to CS 25.1459(e). As a minimum, a discrete signal, indicating when the EFVS image is displayed, must be recorded in addition to the "HUD in use" parameter.
- (v) Vertical Guidance. For approach operations with EFVS it is recommended to provide vertical guidance information of adequate accuracy and integrity.
- (vi) Decision Height Determination. A radio altimeter with display at each pilot's station may be required for operations with minima based on actual height or may be provided to enhance situational awareness.
- (vii) Co-Pilot's Repeater Display. An additional view of the EFVS image for the pilot not-flying (PNF) is needed to address multi-pilot philosophy (operations in RVRs below 550m will require two pilots operation). It enables the PNF to be kept in the 'loop' and crew resource management will not break down. The PNF can be isolated from the information necessary for monitoring flight progress and decision making if the flying pilot is the only one that would have access to the EFVS image. (See also ED-179, paragraph 3.2.5.3.)

d) Testing Requirements

EASA proposes to apply the objectives as specified in ED-179, Appendix F "Sample EFVS Flight Test Plan".

Testing should include all phases of flight for which the applicant seeks approval of the system. In particular each applicable type of approach should be part of the demonstration: E.g. visual, Cat1, FMS (VNAV and VGP), Cat1, Cat2, HUD3, circle-to-land. Evaluation should also cover the different HUD configurations relevant for these approaches: e.g. with and without path reference angle, with and without flight director, with and without declutter.

5. Miscellaneous: fairing substantiation

The location, attachment and shape of the infrared camera fairing should be appropriately substantiated in accordance with the F7X certified flight envelope. At least the following aspects should be addressed: aircraft performance (drag), high speed (V_{Fc}/M_{Fc}) and low speed characteristics (Stall Warning), anemometry impact (RVSM), icing conditions (including failure of the heating system).